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16. ABSTRACT

A manual for control of hazardous material spills using improvised treatment systems was developed under this contract. Spill control techniques have been emphasized, although a brief overview of spill prevention methodology is included. The main body of the manual has been subdivided into eight chapters. The following topics are covered: 1) notification, 2) an inventory of information sources, 3) identification and assessment of human danger potentials, 4) determination of the best handling method, including a thought guide question approach to specific spill incidents and suggested treatment schemes for 303 hazardous chemicals, 5) safety considerations and a limiting factor process design, 6) construction and operation of five improvised treatment processes (filtration, carbon adsorption, ion exchange, gravity separation and chemical reaction), 7) process components and treatment chemicals and 8) standard sampling and record keeping procedures.

It is stressed that previous familiarization with the contents is necessary for its effective use and that the improvised systems should be used only when other equipment is unavailable. Suggested treatment schemes and procedures have not been field tested, so extreme care must be taken to follow all safety precautions. The report is submitted in fulfillment of contract 68-03-2214 by Envirex Inc. and covers the period June, 1975 to June, 1977.

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VOLUME ONE
SPILL ASSESSMENT AND WATER TREATMENT TECHNIQUES

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory, Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report contains suggested procedures for control of hazardous material spills using improvised treatment processes. The methods presented should be used as a last resort in hazardous spill control but do provide an alternative treatment approach if more sophisticated equipment is not available. This Manual includes sections regarding: notification procedures, an inventory of information sources, methods for spill identification and assessment, a thought guide for determining the best method of handling a spill, plus suggested treatment schemes for the 303 designated hazardous chemicals, a limiting factor system design approach, and design, construction and operation steps for each of the five treatment processes applicable to improvised systems. The Manual will be updated periodically to insure the contents are current. Further information on the control of hazardous material spills may be obtained from the Oil and Hazardous Materials Spills Branch (IERL-Ci), Edison, New Jersey 08817.

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Director
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ABSTRACT

This report involved the development of a Manual for hazardous material spills control. This manual is intended for use by people in charge of a spill clean-up operation or their designated representative, and is not limited to EPA or U.S. Coast Guard on-scene coordinators. Prior familiarization with the contents is critical for effective use of the procedures outlined. Since development equipment is often unavailable for immediate use at a spill site, emphasis has been placed on using improvised systems to treat hazardous materials. However, it is stressed that the procedures presented have not been field tested, and that any improvised system is inherently unsafe. Therefore, extreme care must be taken to follow all safety precautions and additional instruction in dealing with hazardous material spills through training courses, is desired.

This Manual has emphasized spill control, although it is recognized that prevention techniques are critical and a brief overview of these methods is included. The control section has been subdivided into eight chapters with paragraph numbering to aid in cross-referencing. Chapter 1 involves notification procedures which are established by the location of the manual user. An inventory of sources which will provide additional chemical information is included in Chapter 2.

Chapter 3 presents possible identification methods and then relies on CHRIS-Vol. 3, Hazard Assessment, for establishing human danger potential. Chapter 4 presents a thought guide approach for determining the best spill handling method for a given situation. In addition, suggested treatment schemes for 303 hazardous chemicals are included. Necessary safety procedures and process design, using a limiting factor approach, are presented in Chapter 5. Chapter 6 includes construction and operation details for the five improvised treatment processes (filtration, carbon adsorption, ion exchanges, gravity separation and chemical reaction). Treatment components and chemical considerations are included in Chapter 7 and Chapter 8 includes sampling and record keeping instruction.

This report was submitted in fulfillment of Contract No. 68-03-2214 under sponsorship of the Environmental Protection Agency. The project was performed by the Environmental Sciences Division of Envirex Inc. This report covers work begun in June, 1975 and completed in June, 1977.

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SECTION I

INTRODUCTION

Increased concern over and regulations concerning the spills of hazardous materials into the environment, along with increasing use of toxic chemicals, have resulted in a growing necessity for treating spills. A spill situation requires immediate response for containment and then treatment of the contaminated media. However, only a limited supply of existing equipment is available for hazardous spill control. Therefore, this Manual was developed to present possible improvised treatment processes for hazardous spill mitigation. In addition, general information required by those using this Manual, including notification procedures, additional information sources, and identification and assessment techniques, are included. Suggested treatment processes for each of the 303 hazardous chemicals are included, but it must be emphasized that they have not been field tested.

This Manual is intended for use by people in charge of a spill cleanup operation and/or their designated representative at the scene of the spill. It is not limited to use by EPA or US Coast Guard on-scene coordinators, but is applicable to various industry personnel or others dealing with hazardous chemicals. The main requirement for effective use of this Manual is to understand the basis for its development and be familiar with the contents prior to a spill occurrence. It is also desirable to have additional instruction in dealing with hazardous chemical spills through training courses such as those offered by National Fire Protection Association (NFPA) or Vanderbilt University. Finally, the Manual should be used in conjunction with many other references that must be readily available to the user.

Prior to the detailed use of this Manual, several important factors must be considered. The first factor is that the improvised treatment processes as proposed are presented as a last resort method for treatment. More sophisticated and, therefore, safer equipment might be available and should be used, if possible. Another consideration is that the proposed equipment designs are just one alternative approach to the development of the unit processes. Imaginative spill control coordinators can modify the design depending upon available materials, site restrictions, etc. It must also be re-emphasized that these methods and the treatment schemes have not been field tested. Interfering factors at a spill site may affect the treatment in an adverse manner and a spill control coordinator must be aware of these possible problems. Strict enforcement of safety procedures is mandatory for safe spill control. Also, an appointed safety director must be aware of potential safety hazards and inform personnel of the risks involved.

Due to the complexity of potential spill events, this Manual has presented a generalized approach to spill control. Each of the 303 hazardous chemicals have been considered separately when the suggested treatment schemes were developed. Mixtures must be handled with care by consulting references and manufacturing experts who can indicate possible chemical by-products. The treatment schemes presented in this Manual are basically concentration processes. The residuals of treatment, including sludges and spent media, must be disposed of properly. However, this Manual does not attempt to address the complicated problems of disposal.

This Manual considers both spill control and spill prevention. The emphasis has been on spill control. A summary section which considers spill prevention techniques is included. Further reference to other documents dealing with spill prevention is recommended. Section IV, entitled "Methodology for Spill Control" contains the major emphasis for on-site spill handling. It has been divided into chapters with subdivision numbering for cross-references. The eight chapters deal with different, but related aspects of spill control. Reference to specialized documents in certain areas has been included and it will be necessary for the spill coordinator to have this additional information readily available. Also, there are certain sections of this Manual which require major input by the spill control coordinator who may use this Manual. This is the situation when considering local spill notification requirements, and identifying local suppliers of equipments and auxiliary chemicals.

The following chapters are included:

Chapter 1: Notification

This chapter briefly discusses the legal requirements for notification. However, it requires some preparatory work by the user since individual notification requirements vary by locality. The local government and appropriate state agency must be contacted to determine actual notification requirements, and lists of these agencies are included.

Chapter 2: Information Sources

This chapter provides a brief inventory of various information sources that are available to aid in the event of a spill situation. The sources have not been evaluated but have only been listed with their information capabilities and access telephone numbers.

Chapter 3: Identification and Assessment

In this chapter, various steps to allow identification of the chemical spilled and then to assess the human danger potential are included. It is emphasized that only an on-scene coordinator or a designated representative should follow the procedures and then only if the appropriate safety precautions are taken. If the identity of a spill is completely unknown, it is not recommended that the spill be approached. The assessment portion of the chapter relies heavily on reference to CHRIS Volume 3 "Hazard Assessment", since duplication of the information presented there was not desirable. Suggestions for collecting needed information at the spill site are included for field use.

Chapter 4: Determination of the Best Method for Spill Handling

Chapter 4 presents a brief overview of containment methods and relies on oil spill control references to provide the needed details. The next portion of the chapter includes a thought guide model which allows determination of the best method for handling a spill given various considerations.

Once this decision is reached, the various handling methods are discussed with emphasis on off-stream but on-site treatment methods. Suggested methods of treating the 303 hazardous chemicals are included, but none of the methods have been field tested. They were developed based on industrial wastewater treatment methods, when available, chemical properties and the knowledge of experienced personnel. References are included to allow further research.

Chapter 5: Safety Precautions and System Design

Once it has been established from Chapter 4 that treatment off-stream but on-site is desirable, then the system must be designed. Chapter 5 first lists other equipment sources that should be used if available. If it is necessary to jury-rig a treatment process, strict safety procedures outlined in this chapter should be followed. Finally, in order to design the most effective system prior to construction, a limiting factor approach is desirable. In this procedure, several different variables are considered and the limiting design flow rate is established. Three examples illustrate the technique.

Chapter 6: Process Construction and Operation

This chapter provides description of each of the five unit processes plus detailed instructions regarding performance of appropriate bench tests. Their individual design and construction steps are included. Finally, operation and troubleshooting directions are included for use in the actual treatment.

Chapter 7: Process Components and Treatment Chemicals

A wide variety of critical information is included in this chapter regarding the individual components of the treatment train. Information given includes tank and pump sizing and selection, hoses and fitting specification, and materials of construction. Treatment chemical information includes data sheets providing pertinent properties and a partial list of suppliers. It is recommended that the user of this Manual list potential suppliers of all treatment chemicals and other equipment before a spill occurrence.

Chapter 8: Standard Operating Procedure During Clean-Up

Information regarding sampling and record keeping procedures to be used during the clean-up operation are included. Both composite and grab samples are discussed along with the mechanics of collection and appropriate sample locations. Sample bottle preparation, sample identification and chain of custody procedures are also presented. Record keeping involves a detailed notation of the field occurrences. Several important records are presented.

This Manual provides a broad range of information for the spill coordinator. But it must be re-emphasized that none of the procedures, with the possible exception of safety precautions are mandatory. The various situations which occur at a spill site cannot be anticipated, so that the procedures presented in this Manual must be applied with caution. The dangers associated in handling a spilled hazardous material cannot be underestimated, so it is strongly recommended that safety be the first priority of those on the scene of a spill.

SECTION II

CONCLUSIONS

GENERAL

In order for this Manual to be effective, it is essential that its potential users be thoroughly familiar with its contents and method of use prior to an actual spill situation.

This Manual contains the minimum required information for treating hazardous spills in improvised field situations. It is necessary to have available for immediate use other, more detailed, references specified in this text.

In addition to this Manual, training courses are available to aid personnel in charge of Hazardous Materials spill control. Among the courses offered are a week-long program through Vanderbilt University, a National Fire Protection Association course on control of accidental releases of hazardous chemicals, and others.

SAFETY AND HAZARD ASSESSMENT

The control of hazardous materials spills presents inherently unsafe conditions for personnel and these problems are compounded when improvised equipment is utilized. Therefore, the suggested procedures included in this Manual should be used only when other equipment is not available. Extreme caution is necessary when performing any task and prior awareness of the risks involved is essential. If the identity of the materials spilled is unknown, the safety hazards cannot be defined. Therefore, the spill should not be approached, without a complete protective enclosure or suit offering maximum isolation from the "worst case" spilled material.

This Manual presents only the basic requirements for one method of field implementation of the suggested treatment processes. It is anticipated that in many field situations, even these requirements cannot be met. Therefore, this Manual is not intended to replace well-trained quick thinking personnel in charge of spill control, but rather it is to serve as an aid and primary reference for their use.

Each person likely to be confronted with a spill should determine the proper reporting procedure before any actual spill occurs. In addition to the requirements of National and Regional Contingency Plans, the state reporting requirements must also be met. According to U.S. Coast Guard Regulation, spills of hazardous substances that may affect water sources should be reported to the National Spill Response Center, 800-424-8802.

Information sources presented in this document have not been evaluated, but rather have been included to provide a broad base of additional needed input.

Identification of a hazardous spill material can be accomplished and verified by the following methods: examination of shipping papers, recognition of physical properties, analysis for chemical properties, or confirmation with the manufacturer or shipper.

Information needed for proper assessment of the hazard potential of a spill should be collected by the spill control coordinator or a designated representative (defined in this Manual as the Man on the Scene (MOS) and relayed to others for further analysis, if needed.

RESPONSE DECISION ANALYSIS

Immediate remedial action, including proper containment methods, is specific to each spill situation. Instructions for implementing remedial action can only be issued after the spill has been identified and assessed.

There are three basic methods available for handling a hazardous spill. The methods are 1) collecting and hauling the material to a remote location, 2) in-situ treatment of the contaminated media, and 3) treatment in an off-stream but on-site treatment system. As a means of last resort, dilution and dispersal may have to be used to minimize the local impact of a concentrated spill.

Determining the best method of handling a spill requires the evaluation of many variables which affect the situation and will ultimately lead to a logical solution.

Although improvised treatment schemes have been suggested for the 303 chemicals designated as hazardous by the U.S. Environmental Protection Agency, many factors, including personnel safety, may dictate on-site treatment to be the least feasible of all available alternatives.

A "limiting factors design" approach has been developed to allow a determination of those variables that control the rate (and thus the time required) at which the hazardous spill may be treated.

Generally, on-site or in-situ treatment (as opposed to hauling or pumping to a remote location) is the best method of spill cleanup only when the hazardous material has entered a body of water or has been highly diluted by some other means.

WATER TREATMENT METHODS

It was found that five basic unit processes would be sufficient for the combination of treatment processes required for treating most of the 303 materials of concern. These processes are 1) filtration, 2) carbon adsorption, 3) ion exchange, 4) gravity separation, and 5) chemical reaction (oxidation/reduction, neutralization, and precipitation).

Batch processes are necessary in improvised treatment systems for many processes because of the unavailability of sophisticated instrumentation for synchronization. However, by constructing a number of batch processes in parallel, a near continuous mode of operation can be achieved.

The use of equalization tanks between individual unit processes simplifies the operation and interconnection logistics between batch processes (e.g., gravity separation and chemical treatment) and continuous flow-through processes (e.g., filtration, carbon adsorption and ion exchange).

Design procedures are outlined for sizing holding tanks for the effluent from the treatment process until analytical results are available. However, the turnover time of the analytical tests, if not performed on site, may require the implementation of an unreasonably large number of storage tanks.

The suggested materials for construction of the treatment processes are those that are readily available from many sources. However, in cases where the easily accessible materials cannot accomplish a task safely (e.g., pumping of corrosive treatment materials), it was necessary to specify special equipment.

The suggested treatment process chemicals have been limited to those that are readily available from chemical supply houses.

SECTION III

RECOMMENDATIONS

1. Identification of people in a given geographical area with expertise in control of hazardous materials should be made and then listed with phone numbers for immediate reference. Also, sources of reliable supplies of common materials and equipment used for spill cleanup should be listed and continually updated.

2. Central storage locations should be developed where common equipment items such as chemicals, tanks, booms, carbon, filter media, etc., can be stored in inventory so that these materials will be readily available on a payback basis when a spill occurs.

3. This Manual should ultimately be divided into two separate parts. The first part would contain the appropriate chapters on notification, spill identification, and assessment. This document would have very broad distribution, including local fire departments, etc. The second part, that would contain extensive information on spill treatment, would have a much smaller distribution.

4. The number of hazardous materials covered in this Manual should be increased to include all those presently listed in OHM-TADS and CHRIS.

5. The treatment schemes suggested in this Manual were based on the existing literature coupled with the contractor's experience in this field. Although the treatment schemes are considered to be applicable, many of these schemes should be field tested. These tests would uncover any obvious shortcomings in design or approach, safety hazards and possible problem areas and would allow recommendation for improved construction and treatment procedures.

6. Since bench scale treatability studies are an integral part of using this Manual, persons intending to use them should be trained in these techniques. Also, bench scale test kits containing the required chemicals and equipment should be assembled and available in each central hazardous spill response location.

7. A research study should be performed to develop simple tests for quantitative and rapid analysis of toxic and hazardous materials. These tests must be applicable for on-site use with a minimum of sophisticated equipment.

8. All sources providing information with regard to the potential safety hazards of a spilled material should devise a common reporting format of input for use by on-site personnel.

SECTION IV

METHODOLOGY FOR SPILL CONTROL

This section of the report contains the main thrust of the manual itself. The techniques to control spills have been presented using a numbered chapter format for ease of cross-reference. The section has been divided into 8 chapters as follows:

Chapter 1: Notification
Chapter 2: Information Sources
Chapter 3: Identification and Assessment
Chapter 4: Determination of the Best Method for Spill Handling
Chapter 5: Safety Considerations and Process Design
Chapter 6: Process Construction and Operation
Chapter 7: Process Components and Treatment Chemicals
Chapter 8: Standard Operating Procedure During Clean-up

As previously stated, it is important for the user of this Manual to be familiar with the content and have previously completed certain information sections. The chapters have been presented in the basic order in which they will be most useful, however, it will be necessary to refer to other chapters, especially during the process design. Therefore overall familiarity with the manual is critical for its most effective use.

1.0 CHAPTER I - NOTIFICATION

1.1 GENERAL

The objective of this chapter is to assist and encourage the user of this manual to determine the proper initial notification procedure for the immediate reporting of a hazardous material spill in his area. This procedure should be determined before any actual spill occurs. It is intended that each user enter the proper contacts and telephone numbers in Table I as he finds appropriate. In this regard the National, State, and Regional Contingency Plans should serve as reference documents and should be kept with this manual. It should be pointed out that all reporting requirements must be met and that State reporting requirements are often more encompassing than Federal requirements. For example, a spill on land only may be covered by State but not by Federal regulation. Also, this discussion covers initial and immediate reporting only; there may also be requirements for later detailed reports to the Regional or State Response Centers and the U.S. Department of Transportation.

It is the responsibility of the user of this Manual to be aware of the regional reporting requirements. To aid in this determination, Tables 2-5 have been included. These tables include the appropriate State and Federal agencies to be contacted in various areas. Telephone numbers have been included where possible although they change periodically; the appropriate agencies should be contacted to determine their current reporting numbers. The needed information regarding notification requirements should be transferred to Table I for future reference.

1.2 PERTINENT FEDERAL REGULATIONS

The National Oil and Hazardous Substances Pollution Contingency Plan was developed in compliance with the Federal Water Pollution Control Act (Public Law 92-500). The Plan provides for a pattern of coordinated and integrated response by Departments and Agencies of the Federal Government to protect the environment from the damaging effects of pollution discharges. The Plan as published in the Federal Register, Vol. 40, No. 28- outlines the notification requirements. In this regard Annex V of the Plan states:

> "1503.2 The initial reporting of a pollution discharge by agencies participating in this plan shall be in accordance with the information and format as described in the regional plans. Reports of medium or major discharge received from discharges or the general public by the National Response Center (NRC) shall be relayed by telephone to predesignated On-Scene Coordinator (OSC)."

The Plan also specified the National Response Center, located at Headquarters, U.S. Coast Guard, Washington, D.C., as the headquarters site for activities relative to pollution emergencies. The National Response Team, consisting of representatives from various Federal agencies, serves planning and response functions and is to work closely with the National Response Center.

TABLE 1. INITIAL NOTIFICATION PROCEDURE FOR HAZARDOUS MATERIAL SPILLS (to be completed by user)

Agency **Comments**

1. **Name:** National Response Center
Address: Headquarters, U.S. Coast Guard
Washington, D.C.
Contact: NRC Duty Officer
Tel. No.: 800/424-8802 (24-hr)

2. **Name:** U.S. EPA Regional Office
Region No. ____________
Address: ____________
____
Contact: ____________
Tel. No.: ____________ (day)
____________ (night)

3. **Name:** U.S. Coast Guard District Office
District No. ____________
Address: ____________
____
Contact: ____________
Tel. No.: ____________ (day)
____________ (night)

4. **State Agency:** ____________
Address: ____________
____
Contact: ____________
Tel. No.: ____________ (day)
____________ (night)

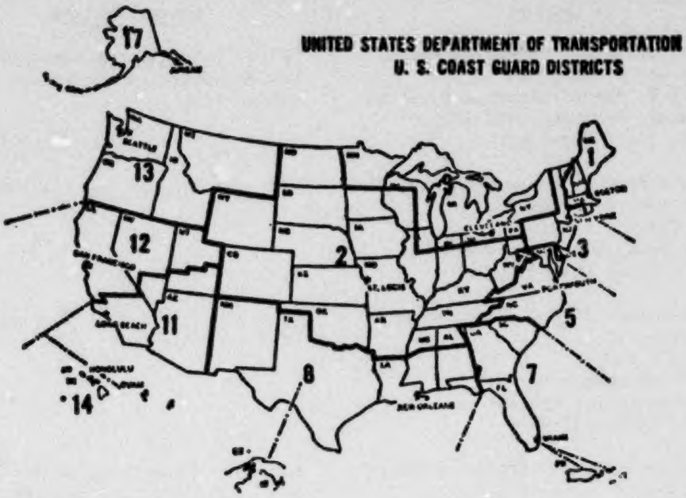
5. For spill on or near international waters

Foreign Govt. Agency: ____________
Address: ____________
____
Contact: ____________
Tel. No.: ____________ (day)
____________ (night)

TABLE 2. EPA REGIONAL OFFICES

	Region	States Included
I.	Environmental Protection Agency Region I, Room 2303 John F. Kennedy Federal Building Boston, Massachusetts 02203 Tel: (617) 223-7265	Maine, Vermont, New Hampshire, Massachusetts, Rhode Island and Connecticut
II.	Environmental Protection Agency Regional II, Room 908 26 Federal Plaza New York, New York 10007 Tel: (201) 548-8730	New York, New Jersey and Puerto Rico
III.	Environmental Protection Agency Region III Curtis Bldg. 6th and Walnut Streets Philadelphia, Pennsylvania 19106 Tel: (215) 597-9898	Pennsylvania, Maryland, Delaware, West Virginia and Virginia
IV.	Environmental Protection Agency Region IV 1421 Peachtree St., N.E. Atlanta, Georgia 30309 Tel: (404) 526-5062	Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi and Florida
V.	Environmental Protection Agency Region V 230 South Dearborn Street Chicago, Illinois 60604 Tel: (312) 896-7591	Ohio, Michigan, Indiana, Illinois Wisconsin and Minnesota
VI.	Environmental Protection Agency Region VI, Suite 1600 1600 Patterson St. Dallas, Texas 75201 Tel: (214) 749-3840	Arkansas, Louisiana, Oklahoma, Texas and New Mexico
VII.	Environmental Protection Agency Region VII 1735 Baltimore Ave. Kansas City, Missouri 64108 Tel: (816) 374-3778	Iowa, Missouri, Nebraska and Kansas
VIII.	Environmental Protection Agency Region VIII, Suite 900 1860 Lincoln Street Denver, Colorado 80203 Tel: (303) 837-3880	North Dakota, South Dakota, Montana, Wyoming, Utah and Colorado
IX.	Environmental Protection Agency Region IX 100 California Street San Francisco, California 94111 Tel: (415) 556-6254	Nevada, Arizona, California, Hawaii and Guam
X.	Environmental Protection Agency Region X 1200 Sixth Avenue Seattle, Washington 98101 Tel: (206) 442-4343	Idaho, Oregon, Washington and Alaska

TABLE 3. U.S. COAST GUARD DISTRICTS


UNITED STATES DEPARTMENT OF TRANSPORTATION
U. S. COAST GUARD DISTRICTS
17
13
12
11
14
8
2
1
3
5
7

1st Coast Guard District
150 Causeway Street
Boston, Mass. 02114
Duty Officer: (617) 223-6650

2nd Coast Guard District
Federal Building
1520 Market Street
St. Louis, Mo. 63101
Duty Officer: (314) 622-4614

3rd Coast Guard District
Governors Island
New York, N.Y. 10004
Duty Officer: (212) 264-4800

5th Coast Guard District
Federal Building
431 Crawford Street
Portsmouth, Va. 23705
Duty Officer: (703) 393-9611

7th Coast Guard District
Room 1018, Federal Bldg.
51 S.W. 1st Avenue
Miami, Fla. 33130
Duty Officer: (305) 350-5611

8th Coast Guard District
Customhouse
New Orleans, La. 7013C
Duty Officer: (504) 527-6225

9th Coast Guard District
1240 East 9th Street
Cleveland, Ohio 44199
Duty Officer: (216) 522-3984

11th Coast Guard District
Heartwell Bldg.
19 Pine Avenue
Long Beach, Calif. 90802
Duty Officer: (213) 590-2311

12th Coast Guard District
630 Sansome Street
San Francisco, Calif. 94126
Duty Officer: (415) 556-5500

13th Coast Guard District
618 2nd Avenue
Seattle, Washington 95104
Duty Officer: (206) 524-2902

14th Coast Guard District
677 Ala Moana Blvd.
Honolulu, Hawaii 96813
Duty Officer: (808) 546-7109
(Commercial Only)
AUTOVON 421-4845

17th Coast Guard District
P.O. Box 3-5000
Juneau, Alaska 99801
Duty Officer: (907) 586-7340
(Commercial Only)
AUTOVON 388-1121

TABLE 4. CANADIAN ENVIRONMENTAL PROTECTION SERVICE EMERGENCY CONTACT LIST

ATLANTIC REGION

Halifax

RD: Dr. C. J. Edmonds
P.O. Box 2406
Halifax, N.S.

EEC: Mr. H. T. Doane
P.O. Box 2406
Halifax, N.S.

Newfoundland

DM: Mr. I. G. Sherbin
Building 310
Pleasantville
St. John's,
Newfoundland A1A 2Y3

NATIONAL HEADQUARTERS

Ottawa

National Manager: Mr. R. A. Beach
15th Floor
Place Vincent Massey
Ottawa, Ontario
K1A 0H3

Assistant Manager
National Environmental
Emergency Centre:

15th Floor
Place Vincent Massey
Ottawa, Ontario
K1A 0H3

QUEBEC REGION

Montreal

RD: Mr. G. M. Gauthier
P.O. Box 1330
Station B
Montreal 110, Quebec

EEC: Mr. Y. Plunier
P.O. Box 1330
Station B
Montreal 110, Quebec

Toronto

RD: Dr. R. W. Slater
135 St. Clair Ave., N
Toronto, Ontario
M4V 1P5

EEC: Mr. N. Vanderkooy
135 St. Clair Ave., W
Toronto, Ontario
M4V 1P5

Ottawa

National Capital Area Manager:

Mr. L. J. Kamp
45 Spancer St.
Ottawa, Ontario
K1Y 2P5

continued

NOTE: RD: Regional Director EEC: Environmental Emergency Coordinator DM: District Manager

TABLE 4 (continued)

NORTHWEST REGION

Edmonton

RD: Mr. J. J. Eatock
10th Floor
Imperial Oil Building
10025 Jasper Ave.
Edmonton, Alberta
T5J 2X9

EEC: Mr. R. K. Pettigrew
10th Floor
Imperial Oil Building
1005 Jasper Ave.
Edmonton, Alberta
T5J 2X9

Winnipeg

DM: Mr. H. C. R. Gavin
9th Floor
303 Main St.
Winnipeg, Maintoba
R3C 3G7

Yellowknife

DM: Mr. W. J. Bryant
9th Floor
Bellanca Bldg.
Yellowknife, N.W.T.

Vancouver

RD: Mr. R. E. McLaren
Kapilano 100
Park Royal
Vancouver, B.C.
V7T 1A2

Whitehorse

DM: Mr. C. E. Wykes
Room 102
Mainsteele Building
212 Main St.
Whitehorse, Y.T.
Y1A 2B1

TABLE 5. APPROPRIATE STATE AGENCIES TO CONTACT

ALASKA	Dept. of Environmental Conservation Pouch 0 Juneau, AK 99801
ALABAMA	Alabama Water Improvement Commission State Office Bldg. Montgomery, AL 36104
ARIZONA	State Department of Health Services Environmental Health Services Division Bureau of Water Quality Control 1740 W. Adams Phoenix, AZ 85007
ARKANSAS	Department of Pollution Control and Ecology Water Division 8001 National Drive Little Rock, AR 72209
CALIFORNIA	State Water Resources Control Board Legal & Enforcement Section P.O. Box 100 Sacramento, CA 95801
COLORADO	Colorado Dept. of Health Water Quality Control Division 4210 E. 11th Avenue Denver, CO 80220
CONNECTICUT	Department of Environmental Protection 165 Capitol Avenue Hartford, CT 06115
DELAWARE	Department of Natural Resources Division of Environmental Control Tatnall Building Dover, DE 19901
FLORIDA	Department of Environmental Regulation 2562 Executive Center Circle East Montgomery Building Tallahasee, FL 32301

continued

TABLE 5. (continued)

GEORGIA	Department of Natural Resources Environmental Protection Division 270 Washington Street, S.W. Atlanta, GA 30334
HAWAII	Environmental Protection & Health Services Division P.O. Box 3378 Honolulu, HI 96801
IDAHO	Dept. of Health & Welfare Division of Environment Statehouse Boise, ID 83720
ILLINOIS	Environmental Protection Agency 2200 Churchill Road Springfield, IL 62706
INDIANA	Indiana Stream Pollution Control Board 1330 West Michigan Street Indianapolis, IN 46206
IOWA	Iowa Water Quality Commission Department of Environmental Quality P.O. Box 3326 Des Moines, IA 50319
KANSAS	State Department of Health & Environment Division of Environment Topeka, KS 66620
KENTUCKY	Department for Natural Resources and Environmental Protection Division of Water Capitol Plaza Tower Frankfort, KY 40601
LOUISIANA	Louisiana Stream Control Commission P.O. Drawer FC University Station Baton Rouge, LA 70803

continued

TABLE 5 (continued)

MAINE	Maine Department of Environmental Protection State House Augusta, ME 04330
MARYLAND	Water Resources Administration Tawes State Office Building Annapolis, MD 21401
MASSACHUSETTS	Division of Water Pollution Control 100 Cambridge St. Boston, MA 02202
MICHIGAN	Dept. of Natural Resources Water Quality Commission 84 Mason Bldg. Lansing, MI 48926
MINNESOTA	Minnesota Pollution Control Agency 1935 W. County Rd. B2 Roseville, MN 55113
MISSISSIPPI	Mississippi Air & Water Pollution Control Commission P.O. Box 827 Jackson, MS 39205
MISSOURI	Department of Natural Resources Division of Environmental Quality Water Quality Program P.O. Box 1368 Jefferson City, MO 65101
MONTANA	Dept. of Health & Environmental Sciences Water Quality Bureau Cogswell Building Helena, MT 59601
NEVADA	State Environmental Commission 102 Johnson St. Carson City, NV 89701
NEW HAMPSHIRE	New Hampshire Water Supply & Pollution Control Commission 105 Loudon Rd. Concord, NH 03301

continued

TABLE 5 (continued)

NEW JERSEY	N.J. Dept. of Environmental Protection Division of Water Resources P.O. Box 2809 Trenton, NJ 08625
NEW MEXICO	Environmental Improvement Agency Water Quality Division P.O. Box 2348 Santa Fe, NM 87503
NEW YORK	State Dept. of Environmental Conservation Bureau of Monitoring & Surveillance 50 Wolf Road, Rm 306 Albany, NY 12201
NORTH CAROLINA	Dept. of Natural & Economic Resources Division of Environmental Management P.O. Box 27687 Raleigh, NC 27611
NORTH DAKOTA	State Dept. of Health Division of Environmental Engineering State Capital Building Bismarck, ND 58501
OHIO	Ohio Environmental Protection Agency P.O. Box 1049 Columbus, OH 43216
OKLAHOMA	State Dept. of Health Occupational & Radiological Health Service P.O. Box 53551 Oklahoma City, OK 73105
OREGON	State Department of Environmental Quality 1234 S.W. Morrison Portland, OR 97205
PENNSYLVANIA	Dept. of Environmental Resources Bureau of Water Quality Management P.O. Box 2063 Harrisburg, PA 17120

continued

TABLE 5. (continued)

PUERTO RICO	Environmental Quality Board San Juan, Puerto Rico 00910
RHODE ISLAND	Rhode Island Dept. of Health Division of Water Supply & Pollution Control 209 Health Building Davis Street Providence, RI 02908
SOUTH CAROLINA	Office of Environmental Quality Control Monitoring Division J. Marion Sims Building 2600 Bull St. Columbia, SC 29201
SOUTH DAKOTA	Dept. of Environmental Protection Joe Foss Building Pierre, SD 57501
TENNESSEE	Tennessee Division of Water Quality Control 621 Cordell Hull Building Nashville, TN 37219
TEXAS	Water Quality Control Board P.O. Box 13246, Capital Station Austin, TX 78711
UTAH	State Division of Health Bureau of Water Quality 44 Medical Drive Salt Lake City, UT 84113
VERMONT	Agency of Environmental Conservation Water Quality Division State Office Bldg. Montpelier, VT 05602
VIRGINIA	State Water Control Board Bureau of Surveillance & Field Studies P.O. Box 11143 Richmond, VA 23219

continued

TABLE 5. (continued)

VIRGIN ISLANDS	Health Department St. Thomas, Virgin Islands 00801
WASHINGTON	State Dept. of Ecology Olympia, WA 98504
WISCONSIN	Department of Natural Resources Bureau of Water Quality P.O. Box 450 Madison, WI 53701
WEST VIRGINIA	Dept. of Natural Resources Division of Water Resources 1201 Greenbrier St. Charleston, WV 25311
WYOMING	Dept. of Environmental Quality Water Quality Division State Office Building West Cheyenne, WY 82002

The Plan also provides for Regional Response Centers and Regional Response Teams. The Regional Response Center is the regional site for pollution emergency response activities. Each region has prepared a contingency plan to deal with oil and hazardous material spills in its region. The Regional Response Team performs response and advisory functions in its specific region.

The user of this Manual should obtain a copy of the contingency plan for his region if he does not have one. The regional contingency plan contains detailed information on the response center location, telephone numbers of the appropriate agencies to contact, and geographic boundaries for the various agencies.

2.0 CHAPTER 2 - INFORMATION SOURCES

2.1 GENERAL

There are a number of information systems whose main function is to provide assistance during hazardous materials spills. These systems are listed in Table 6. There are also information retrieval services - both computerized and manual - which provide information or a list of titles or abstracts of articles dealing with a specific subject. The organizations which provide these services are listed in Table 7. The availability of an on-line computer usually indicates a short turn-around time for responses. This is often important in an emergency situation. There are also available numerous reference texts and handbooks which contain information on the properties of hazardous chemicals. Those likely to be faced with a hazardous material spill may find it helpful to obtain one or more of these books for future reference. Several useful handbooks are listed in this section. Each system designed specifically to provide information on hazardous materials is discussed in terms of what it is, what information it contains, how it operates, and how it can be accessed by responsible people at the emergency scene. The manual does not attempt to provide an evaluation of these information sources, but rather it is only an inventory with pertinent information required for use.

2.2 EPA OIL AND HAZARDOUS MATERIALS TECHNICAL ASSISTANCE DATA SYSTEM (OHM-TADS)

2.2.1 Description

The OHM-TADS is a computerized information retrieval file on more than 850 oil and hazardous substances. The system is presently on-line and available to assist in identification of a spilled material from certain observations (color, smell, etc.) made at the site. For each substance there are 123 information segments (see Figure 1) covering a wide variety of physical, chemical, biological, toxicological, and commercial data with the greatest emphasis on the effects on water quality. Of the 123 segment headers 95 can be used as search components.

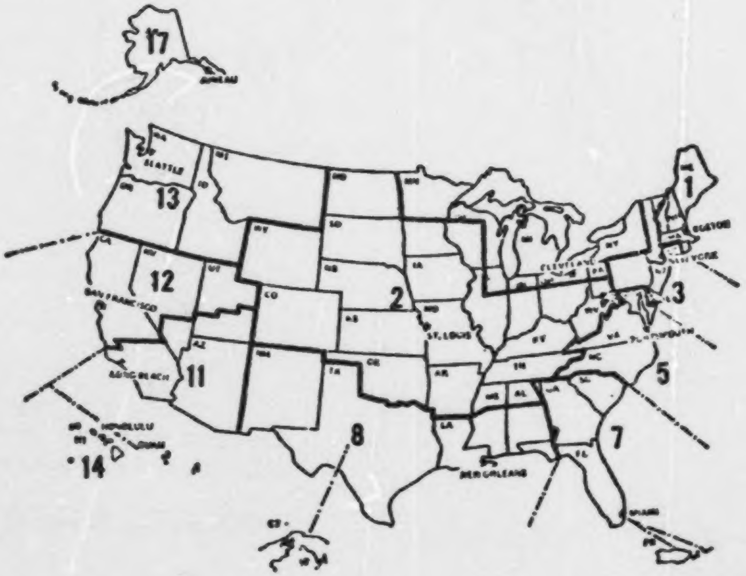
2.2.2 Mode of Operation

The OHM-TADS has a random access provision which enables the user to solve problems involving unidentified pollutants by inputting color, odor or other physical/chemical characteristics as observed on-scene. The system automatically takes each word and processes it into an inverted index file, making each word a search component of the data base. The search is made using Boolean logic and the system responds with a list of the materials meeting the input characteristics. The output is displayed on the user's terminal. The user can then refine the search if necessary to narrow the list of possible materials.

In looking for characteristics of the spill to aid in identification, the 95 searchable headers should be examined to see if any of them can serve as identifiers.

TABLE 6. SOURCES OF INFORMATION/ASSISTANCE FOR HAZARDOUS MATERIAL SPILLS

Information source	Type of Organization	Type of Information Assistance[a]	Access
EPA Oil and Hazardous Materials - Technical Assistance Data System (OHMTADS)	Federal	2-A	EPA Regional Office
Coast Guard Chemical Hazards Response Information System (CHRIS)	federal	2-A	National Response Center Regional Response Centers District Offices:



1st Coast Guard District
150 Causeway Street
Boston, MA 02114
Duty Officer: 617/223-6650

2nd Coast Guard District
Federal Building
1520 Market Street
St. Louis, MO 63101
Duty Officer: 314/622-4614

3rd Coast Guard District
Governors Island
New York, NY 10004
Dlty Officer: 212/264-4800

5th Coast Guard District
Federal Building
431 Crawford Street
Portsmouth, VA 23705
Duty Officer: 703/393-9611

7th Coast Guard District
Room 1018, Federal Bldg.
51 S.W. 1st Ave.
Miami, FL 33130
Duty Officer: 305/350-5611

8th Coast Guard District
Customhouse
New Orleans, LA 70130
Duty Officer: 504/527-6225

9th Coast Guard District
1240 East 9th Street
Cleveland, OH 44199
Duty Officer: 216-522-3934

11th Coast Guard District
Heartwell Bldg.
19 Pine Avenue
Long Beach, CA 90802
Duty Officer: 213-590-2311

12th Coast Guard District
630 Sansome Street
San Francisco, CA 94126
Duty Officer: 415-556-5500

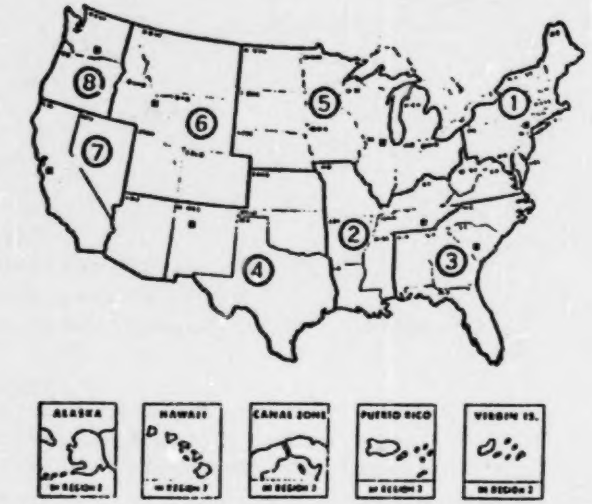
13th Coast Guard District
618 2nd Avenue
Seattle, WA 93104
Duty Officer: 206/524-2902

14th Coast Guard District
677 Ala Moana Blvd.
Honolulu, HA 96813
Duty Officer: 803/456-7109
(COMMERCIAL ONLY)
AUTOVON 421-4845

17th Coast Guard District
P.O. Box 3-5000
Juneau, Alaska 99801
Duty Officer: 907/586-7340
(COMMERCIAL ONLY)
AUTOVON 388-1121

TABLE 6. (continued)

Information source	Organization	Type of Information Assistance	Access
Interagency Regiological Assistance Plan (IRAP)	Federal	1,2	1. CHEMTREC 800/424-8300 (202/483-7616 in Washington, D.C.) 2. Regional Offices:



	Office	P.O. Address	Telephone	DDD Area Code
1.	Brookhaven Area Office	Upton L.I. New York 11973	345-2200	516
2.	Oak Ridge Oper. Office	P.O. Box E Oak Ridge, TN 37830	480-8617 Ext. 4510	615
3.	Savannah River Ooerations Office	P.O. Box A Aiken, S.C. 29801	N. August, SC 824-6331 Ext. 3333	803
4.	Albuquerque Operations Office	P.O. Box 5400 Albuquerque New Mexico 87115	264-4667	505
5.	Chicago Operations Office	9300 S. Cass Ave. Argonne Illinois 60439		312
6.	Idaho Operations Office	P.O. Box 2108 Idaho Falls Idaho 83401	526-0111 Ext. 1515	208
7.	San Francisco Operations Office	2111 Bancroft Way Berkeley California 94704	841-5121 Ext. 664 duty hrs 841-9244 off hrs	415
8.	Richland Operations Office	P.O. Box 550 Highland Washington 99352	942-7381	509

TABLE 6. (continued)

Information source	Type of Organization	Type of Information Assistance[a]	Access
Coast Guard National Strike Force	Federal	1	National Response Center (800/424-8802)
U.S. Army Technical Escort Center, Chemical Emergency Response Team	Federal	1	Dept. of Army Operation Center 703/521-2185
Chemical Transportation Emergency Center (CHEMTREC)	Privately sponsored	2,3	Through CHEMTREC 800/424-9300 (in Washington, D.C. 202/483-7616)
Pesticides Safety Team Network	Privately sponsored	1,2,3	Through CHEMTREC 800/424-9300 (in Washington, D.C. 202/483-7616)
Transportation Emergency Assistance Plan (TEAP)	Canadian, privately sponsored	1,2,3	Each regional Control Center has 24 hour number: 1. Hooker Chemicals Division Vancouver, British Columbia 604/929-3441; geographic location: British Columbia 2. Celanese Canada Ltd., Edmonton, Alberta 403/477-8339; geographic location: Prairie Provinces 3. Canadian Industries Ltd., Copper Cliff, Ontario 705/682-2881 geographic location: Northern Ontario

TABLE 6. (continued)

Information source	Organization	Type of Information Assistance[a]	Access
			4. Dow Chemical of Canada, Ltd., Sarnia, Ontario 519/339-3711 geographic location: Central Ontario
			5. Cyanamid of Canada, Ltd., Niagara Falls, Ontario; 416/356-8310 geographical location: Eastern Ontario
			6. DuPont of Canada, Ltd., Maitland, Ontario; 613-348-3616; geographical location: Western Ontario
			7. Allied Chemical Canada Ltd., Valleyfield, Quebec, 514-373-8330 geographical location: Quebec - south of St. Lawrence
			8. Gulf Oil Canada Ltd., Shawinigan, Quebec, 819-537-1123; geographical location: Quebec, north of St. Lawrence
Chlorine Emergency Plan (CHLOREP)	Privately sponsored	1,2,3	Through CHEMTREC - 800/424-9300 (in Washington, D.C. 202/483-7616

[a] 1. Respond to scene with trained personnel if required.
2. Provide information on identity, hazards, or what to do.
3. Refer to knowledgeable contact

A. On-line computer available.

TABLE 7. INFORMATION RETRIEVAL SYSTEMS

Information source	On-line computer system	Contact
Lockheed Information Systems	yes	415/493-4411 Ext. 45635
Editec Inc.	yes	312/427-6760
Illinois Institute for Environmental Quality Library	yes	312/793-3870
Institute for Scientific Information	yes	215/923-3300
NIOSH Technical Information Center	yes	301/443-3063
National Technical Information Service	yes	202-967-4349
National Emergency Equipment Locator System (NEELS-Canadian)	yes	819-997-3742
National Analysis of Trends in Emergencies System (NATES-Canadian)	yes	819/997-3742
NASA - Scientific & Technical Information Office	yes	202-755-3548
NASA - Indus. Applications Cntrs:		
Univ of Conn., Storrs, Ct.	yes	203/486-4533
Research Triangle Park, NC	yes	919/549-8291
Univ of Pittsburg, PA	yes	412/624-5211
Indiana Univ, Bloomington, IN	yes	812-337-8884
Univ of N. Mexico, Albuquerque	yes	505/277-3622
Univ. of S. Cal, Los Angeles, CA	yes	213/746-6132
Global Engineering Documentation Services	no	714/540-9870 213/624-1216
U.S. Dept. of Commerce Maritime Administrator	no	212/967-5136
National Bureau of Standards Fire Technology Library	no	301/921-3246
NASA/Aerospace Safety Research & Date Institute	no	216/443-4000 Ext. 285
Chemical Abstract Service Ohio State University	no	614/421-6940
Computer Search Center Illinois Institute of Tech. Research Institute	no	312/225-9630
Fire Research Section Southwest Research Institute	no	512/684-5111 Ext. 2415
Environmental Engineering Div., Texas A&M University	no	713-845-3011
Toxicology Data Bank, Natl Library of Medicine	no	301-496-1131

*1. TADS Accession No.
2. Material Name
3. Synonyms
4. Trade Names
5. Chemical Formula
*6. Species in Mixture
7. SIC Code
8. Common Uses
*9. Rail (%)
*10. Barge (%)
*11. Truck (%)
*12. Pipeline (%)
13. Containers
14. Shipment Size
15. General Storage Procedures
*16. General Handling Procedures
*17. Personal Safety Precautions
18. Production Sites
*19. Use Areas
20. Hydrolysis Product Of
*21. % Additive
22. Flammability
23. Explosiveness
24. Air Pollution
*25. Action Levels
*26. Field Detection, Limit (ppm) Techniques
*27. Laboratory Detection Limit (ppm), Techniques
28. Major Hazards
29. Standard Codes
30. Melting Point (°C)
31. Melting Characteristics
32. Boiling Point (°C)
33. Boiling Characteristics
34. Solubility (ppm 25°C)
35. Solubility Characteristics
36. Specific Gravity
37. Probable location and state of material
38. Binary Reactants
39. Lower Flammability Limit (%)
40. Upper Flammability Limit (%)

(continued)

(Asterisk indicates non-searchable components, for display only)

Figure 1. Information segment headers in OHM-TADS.

41. Toxic Combustion Products
42. Extinguishing Methods
43. Lower Explosive Limit (%)
44. Upper Explosive Limit (%)
45. Flash Point (°C)
46. Auto Ignition Point (°C)
47. Inhalation Limit (Value)
48. Inhalation Limit (Text)
49. Irritation Levels (Value)
50. Irritation Levels (Text)
51. Direct Contact
52. General Sensation
53. Lower Odor Threshold (ppm)
54. Lower Odor Threshold (Text)
55. Medium Odor Threshold (ppm)
56. Medium Odor Threshold (Text)
57. Upper Odor Threshold (ppm)
58. Upper Odor Threshold (Text)
59. Lower Taste Threshold (ppm)
60. Lower Taste Threshold (Text)
61. Medium Taste Threshold (ppm)
62. Medium Taste Threshold (Text)
63. Upper Taste Threshold (ppm)
64. Upper Taste Threshold (Text)
65. Corrosiveness
66. Synergistic Materials
67. Antagonistic Materials
68. Degree of Hazard to Public Health
69. Exchange Capacity with Natural Soils
70. Industrial Fouling Potential
71. Effect on Water Treatment Process
72. Direct Human Ingestion (mg/kg wt)
*73. Reference for Direct Human Ingestion
74. Recommended Drinking Water Limits (ppm)
*75. Reference for Recommended Drinking Water Limits
76. Body Contact Exposure (ppm)
*77. Reference for Body Contact Exposure
78. Fresh Water Toxicity
79. Limiting Water Quality
80. Salt Water Toxicity
81. Animal Toxicity
82. Livestock Toxicity (ppm)
*83. Reference for Livestock
84. Waterfowl (ppm)

(continued)

Figure I (continued).

*85. Reference for Waterfowl
86. Aquatic Plants (ppm)
*87. Reference for Aquatic Plants
88. Irrigable Plants (ppm)
*89. Reference for Irrigable Plants
90. Major Species Threatened
91. Acute Hazard Level
92. Etiological Potential
93. Emergency Water Quality Std (ppm)
94. Prolonged Human Contact (ppm)
*95. Reference for Prolonged Human Contact
96. Potential for Accumulation
97. Chronic Aquatic Toxicity Limits (ppm)
*98. Reference for Chronic Aquatic Toxic Limit
99. Taste Imparting Characteristics (ppm)
*100. Reference for Taste Imparting Characteristics
101. Chronic Animal Toxicity Limits (ppm)
*102. Reference for Chronic Animal Toxicity Limits
103. Chronic Waterfowl Toxicity Limits (ppm)
*104. Ref. for Chronic Waterfowl Toxicity Limits
105. Chronic Plant Toxicity Limits (ppm)
*106. Ref. for Chronic Plant Toxicity Limits
107. Soil Transformation Properties
108. BOD (lb/lb)
109. In Situ Amelioration
110. Beach and Shore Restoration
*111. Availability of Countermeasure Material
112. Disposal Methods
*113. Disposal Notification
114. Chronic Hazard Level
115. Food Chain Concentration Potential
116. Persistency
117. Major Water Uses Threatened
118. Adequacy of Data
119. Carcinogenicity
120. Mutagenicity
121. Teratogenicity
122. Color in Water
123. Fields Containing Data

Figure 1 (continued)

2.2.3 Access

Access to OHM-TADS is through the oil and hazardous material spill coordinator at the EPA Regional office (Regional Response Center).

2.3 U.S. COAST GUARD CHRIS

2.3.1 Description

This system consists of four manuals, a regional contingency plan, a hazard-assessment computer system (HACS), and an organizational entity at the Coast Guard Station. The four manuals are as follows:

> Vol. 1-CG-446-1 - Condensed Guide to Chemical Hazards - contains essential information on those hazardous chemicals that are shipped in large volumes by marine transportation.
>
> Vol. 2-CG-446-2 - Hazardous Chemical Data Manual - contains detailed information on the chemical, physical, and toxicological properties of hazardous chemicals, in addition to all the information in Vol. 1.
>
> Vol. 3-CG-446-3 - Hazard Assessment Handbook - contains methods of estimating the rate and quantity of hazardous chemicals that may be released and methods for predicting the potential toxic, fire, and explosive hazards.
>
> Vol. 4-CG-446-4 - Response Methods Handbook-contains information on existing methodology for handling spills; the Appendix to this volume contains a list of manufacturers of equipment which may be useful in a spill situation.

The contingency plan is part of the National Contingency Plan as mentioned in Chapter 1. The Hazard - Assessment Computer System is the computerized counterpart of Volume 3 and makes it possible to obtain detailed hazard evaluations. Although calculations can be performed by hand using Vol. 3, the HACS permits one to make a more complex and usually more accurate assessment of the spill situation.

2.3.2 Mode of Operation

Volume 1, Condensed Guide to Chemical Hazards, is intended for use by port security personnel and others who may be first to arrive at the scene of the accident. It contains easily understood information about the hazardous nature of the chemical, assuming the chemical is identified. It is intended to assist those present in quickly determining the actions that must be taken immediately to safeguard life, property and the environment. Volume 1 contains a list of the information needed to assess potential hazardous effects through the use of Volume 3.

Volumes 2, 3, and 4 are intended for use by the On-Scene Coordinator's (OSC) office and the Regional and National Response Centers. Coast

Guard stations, especially those in major ports, will usually also have these manuals. The computer system (HACS) is also designed for use by OSC personnel.

Volumes 2 and 3 are designed to be used together. For example, Vol. 2 The Hazardous Chemical Data Manual contains a hazard-assessment code for each chemical. This code is used in Vol. 3 The Hazard-Assessment Handbook to select the appropriate calculation procedures for the hazard assessment, enabling the user to estimate the rate and quantity of hazardous chemicals that may be released under different situations. For example, procedures are provided for estimating the concentration of hazardous chemicals (both in water and in air) as a function of time and distance from the spill. The Hazard-Assessment Computer System (HACS) is the computerized counterpart of Vol. 3 and makes it possible to obtain detailed hazard evaluations quickly. The HACS system is intended primarily for use by OSC personnel through Coast Guard headquarters. While the input needed for evaluation will depend on the specific accident situation and that part of the system which is to be used, the following information should be supplied to Coast Guard headquarters as applicable.

Material discharged
Quantity spilled
Quantity originally in tank
Location of spill
Time of occurrence
Tank dimensions
Other cargos or nearby chemicals
Hole diameter
River depth
River width
Stream velocity
Temperature (air)
Temperature (water)
Cloud cover (percent)

Depending on which model it is decided to use, other information may be needed by Coast Guard headquarters. In this case a call back number should be given so that headquarters personnel can request additional information if necessary. More information on the use of Vol. 3 is given in Chapter 3 of this report.

Volume 4, The Response Methods Handbook, contains descriptive and technical information on methods of spill (primarily oil) containment. This manual is intended for use by Coast Guard OSC personnel who have had some training or experience in hazard response.

2.3.3 Access

Access to the CHRIS manuals can be obtained through the Coast Guard District office (see Table 6). The HACS can be assessed on an emergency basis through the Regional Response Center, the Coast Guard District office, or directly through the Department of Transportation National Response Center at Coast Guard headquarters.

2.4 INTERAGENCY RADIOLOGICAL ASSISTANCE PLANT (IRAP)

2.4.1 Description

The Interagency Radiological Assistance Plan (IRAP) is designed to assist any person in obtaining technical guidance in coping with radiation emergencies. It operates through the U.S. Energy Research and Development Administration but works closely with other Federal, state, military, and regional groups. In the IRAP the U.S. is divided into eight geographical areas of responsibility each with a regional coordinating office. These areas and the offices with telephone numbers are given in Table 6.

2.4.2 Mode of Operation

Upon receiving an emergency call, the regional coordinator investigates the situation to assess the potential radioactive hazard. He tries to get as much information over the phone on the specifics of the situation and the type of material (e.g. from the shipping papers). Advice will be given over the phone if the potential hazard appears minimal. If the spill or leak appears serious, a technical response team will be dispatched. This team will work jointly with state personnel (civil defense, public health) whenever possible. In any case the coordinating office will notify the appropriate state office of the radioactive spill. When the response team is dispatched, the Nuclear Regulatory Commission is notified especially if the spilled material is licensed. The main functions of the response team are to assess the hazard, to inform people of the hazard, and to recommend emergency actions to minimize the hazard. The responsibility for clean-up rests with the shipper or carrier (the party who has possession of the material at the time of the spill).

2.4.3 Access

Access to the IRAP is through the regional coordinating offices given in Table 6. Each office has a 24-hour emergency telephone number. When reporting an incident, the following information should be given:

1. Name and title of caller
2. Call back number
3. Location and magnitude of problem
4. Information of shipping papers
    - type of material
    - manufacture or shipper
    - carrier

IRAP can also be accessed through CHEMTREC.

2.5 U.S. COAST GUARD NATIONAL STRIKE FORCE

2.5.1 Description

The Coast Guard's National Strike Force (NSF) is part of the National Contingency Plan established under authority of the Federal Water Pollution Control Act Amendments of 1972, Section 311 (1). It consists of high-seas equipment and trained personnel available to assist the On-Scene Coordinator upon request during Phase III (Containment and Countermeasures), Phase IV (Cleanup, Mitigation and Disposal), and Phase V (Documentation and Cost Recovery), as defined in the National Contingency Plan. There are three Coast Guard Strike Teams located on the East, West, and Gulf coasts. Each strike team consists of 18 or 19 men, including 3 or 4 officers. Each strike team is capable of responding to a pollution incident in its area with four or more men within 2 hours and at full strength in 12 hours. The Strike Team can provide communications support and assistance and advice on ship salvage, diving and removal techniques. Available equipment primarily designed for air transport, consists of the following:

1. Air Deliverable Antipollution Transfer System (ADAPTS), consists of a pumping system to off-load stricken cargo vessels.
2. Yokohama fenders, used for side protection during vessel-to-vessel cargo transfer.
3. High-seas containment barrier.
4. High-seas skimmer.

2.5.2 Access

The services of the National Strike Force are available to any On-Scene Coordinator anywhere in the country. Requests for assistance can be made through the National Response Center through its 24-hour emergency telephone number (see Table 6). The specific details of the emergency situation should be given.

2.6 U.S. ARMY TECHNICAL ESCORT CENTER CHEMICAL EMERGENCY RESPONSE TEAM

2.6.1 Description

The U.S. Army Technical Escort Center maintains, on standby, a 14-man alert team at Aberdeen Proving Ground, Maryland, ready to respond to chemical emergencies within 2 hours. If necessary, additional personnel are available for mobilization. The team is trained and experienced in handling chemical emergencies and has available to it special equipment such as decontamination trucks, detection devices, and protective clothing.

2.6.2 Mode of Operation

The U.S. Army Technical Escort Center's team responds to a chemical emergency when directed by the higher command. While the team was formed mainly to respond to emergencies involving Department of the Army chemicals, it has assisted other agencies such as the U.S. Coast Guard.

2.6.3 Access

To obtain the assistance of the escort team, initial contact should be made with the regional EPA office. EPA personnel will then contact the Dept. of the Army Operations Center at the commercial number listed in Table 6. Upon receipt of each request, the Army Operations Center determines if the specific services of the Technial Escort Center are needed. If the determination is made for the emergency team to respond, intermediate commands are notified and the team dispatched. The Commander of the Technical Escort Center should be contacted.

2.7 CHEMICAL TRANSPORTATION EMERGENCY CENTER (CHEMTREC)

2.7.1 Description

CHEMTREC serves a clearinghouse function by providing a single emergency 24-hour telephone number for chemical transportation emergencies. Upon receiving notification of a spill, CHEMTREC immediately contacts the shipper of the chemicals involved for assistance and follow-up. CHEMTREC also provides warning and limited guidance to those at the scene of the emergency if the product can be identified either by the chemical or trade name. The CHEMTREC system covers over 3,600 items which have been submitted by manufacturers as their primary items of shipment. CHEMTREC is sponsored by the Manufacturing Chemists Association although non-members are also served. The system is not computerized.

2.7.2 Mode of Operation

The CHEMTREC emergency telephone number is widely distributed to emergency service personnel, carriers, and throughout the chemical industry. The number is usually given on the bill of lading. When an emergency call is received by CHEMTREC, the person on duty records the essential information in writing. He tries to obtain as much information as possible from the caller. The person on duty will give out information as furnished by the chemical producers on the chemical(s) reported to be involved. This would include information on hazards of spills, fire, or exposure. After advising the caller, the person on-duty immediately notifies the shipper of the chemical by phone, giving him the details of the situation. At this point, responsibility for further guidance passes to the shipper.

CHEMTREC'S function is basically to serve as the liaison between the person with the problem and the chemical shipper and/or manufacturer, the theory being that the manufacturer of the chemical or material will know the most about his product and its properties. CHEMTREC also serves as a contact point for the Chlorine Institute, the National Agricultural Chemicals Association (pesticides), and the Energy Research and Development Administration (radioactive materials).

2.7.3 Access

CHEMTREC can be accessed through its emergency telephone number listed in Table 6. As much of the following information should be provided by the caller as possible:

1. Name of caller and call back number.
2. Location of problem.
3. Shipper or manufacturer
4. Container type
5. Rail car or truck number
6. Carrier name
7. Consignee
8. Local conditions

2.8 NACA PESTICIDES SAFETY TEAM NETWORK

2.8.1 Description

The National Agricultural Chemicals Association through its members operates a national pesticide information and response network. Its function is to provide advice and on-site assistance when the spill situation warrants it.

2.8.2 Mode of Operation

The network operates through the CHEMTREC office. Upon receiving notification of an emergency involving a pesticide, the manufacturer is contacted by CHEMTREC. The manufacturer will provide specific advice regarding the handling of the spill. If necessary, spill response teams are available on a geographical basis to assist at the emergency scene.

2.8.3 Access

Access to the network is through CHEMTREC (see Table 6 for telephone no.)

2.9 TRANSPORTATION EMERGENCY ASSISTANCE PLAN (TEAP), Canadian Chemical Producers' Association (CCPA)

2.9.1 Description

TEAP serves a function in Canada similar to that of CHEMTREC in the U.S. Canada is divided into eight geographic areas, each served by a regional control center. Depending on the location of the spill, one of these control centers is called and notified of the emergency. The functions of TEAP are to provide emergency advice, to get knowledgeable personnel (usually the manufacturer) in touch with responsible people at the emergency scene, and to see that on-the-scene assistance is provided if needed.

2.9.2 Mode of Operation

When a call is received at a regional control center, the attendant records basic information on a record sheet and obtains a call-back number. He may also give preliminary information from standard references if the name of the product is known. The attendant will then call one of the center's technical advisers with the preliminary information. The technical adviser will then call the accident scene to determine as much detail as possible. At this time he may also be able to provide additional advice on coping with the emergency. The adviser will then try to contact the producer from the listed references. If the producer can be contacted, the adviser will turn the problem over to them as the most knowledgeable contact. If the producer cannot be reached, or if distances are great, the regional control centers will contact a company familiar with the product. The center is also prepared to send men and equipment to the scene if necessary. Once contact has been established between the producer and the local authorities on the scene, the technical adviser assumes a follow-up role and notifies the CCPA of the incident.

2.9.3 Access

Access to TEAP is through the regional control centers given in Table 6. Essential information that should be provided includes:

1. Exact name of the product spilled
2. Name of the producer
3. Name of the carrier

2.10 CHLORINE EMERGENCY PLAN (CHLOREP)

2.10.1 Description

Chlorine manufacturers in the U.S. and Canada through the Chlorine Institute have established the Chlorine Emergency Plan to handle chlorine emergencies. This is essentially a mutual aid program whereby the manufacturer closest to the emergency will provide technical assistance even if it involves another manufacturer's product.

2.10.2 Mode of Operation

The CHLOREP system operates through CHEMTREC. Upon receiving an emergency call, CHEMTREC notifies the appropriate party in accord with the mutual aid plan. This party then contacts the emergency scene to determine if it is necessary to send a technical team to provide assistance. Each participating manufacturer has trained personnel and equipment available for emergencies.

2.10.3 Access

Access to CHLOREP on a 24-hour basis is through CHEMTREC (telephone number in Table 6).

2.11 INFORMATION RETRIEVAL SYSTEMS

Organizations providing information retrieval should be considered as secondary sources of information because information is from the published literature or past events, and because interaction is limited since the contact usually has no special expertise in spills technology or hazardous chemicals. A list of information retrieval sources was given in Table 7. Because of the emergency nature of most spills, a short response time is important. In this regard an on-line computerized system is desirable, although a manual search could also have a short turnaround time. Data bases range from spill specific to general scientific. Examples of specific bases are the Canadian NEELS data base which covers the location of publicly and privately owned cleanup equipment and the NATES data base which covers the history of past spills and their cleanup. These two systems are discussed below.

The mode of operation for the computerized systems involves inputting applicable key words as search components. These might include the name of the chemical and words such as "pollution", "water", "removal", "toxicity", "reactivity", and "hazards".

2.12 NATIONAL EMERGENCY EQUIPMENT LOCATOR SYSTEM (NEELS)

2.12.1 Description

NEELS is an on-line computer system designed and operated by the Environmental Protection Service (EPS), Environment Canada. Its function is to provide information on equipment available near the spill scene which may be useful. This includes containment and treatment equipment held both publicly and privately.

2.12.2 Mode of Operation

Connection can be made with the NEELS computer system through any EPS regional office. The longitude and latitude of the spill must be entered as input and the desired output must be selected from the following choices:

1. All equipment at the nearest location.
2. Nearest specific type of equipment.
3. Nearest particular piece of equipment.

Depending on the selection, the computer prints out the location of the equipment and the name of the person and telephone number to call.

2.12.3 Access

Information on gaining access to NEELS can be obtained from the National Environmental Emergency Center by calling the 24-hour emergency number listed in Table 6.

2.13 NATIONAL ANALYSIS OF TRENDS IN EMERGENCIES SYSTEM (NATES)

2.13.1 Description

NATES is an on-line computer system designed and operated by the Environmental Protection Service (EPS), Environment Canada. Its function is to provide information on how a similar spill was handled.

2.13.2 Mode of Operation

Connection can be made with the NATES computer system through any EPS regional office. Main input to the system is the type of material spilled. Output includes data on location, date, material spilled, cause, environment including site conditions and contingency plans, cleanup including method used, weather, agencies involved, legal actions, and cost.

2.13.3 Access

Information on gaining access to NATES can be obtained from the National Environmental Emergency Center by calling the 24-hour emergency number, listed in Table 6.

2.14 USEFUL GUIDES AND REFERENCE HANDBOOKS

There are many handbooks and reference texts which may prove helpful in the event of a hazardous material spill. Any person who may be confronted with a spill emergency should have access to one or more of the commonly used references. In addition, the Regional Response Center maintains a hazardous materials reference library. In particular, the references listed in Table 8 should be available.

TABLE 8. REFERENCES TO USE IN CONJUNCTION WITH THIS MANUAL

Critical References	Critical Reference Source
OHM-TADS Data Sheets	US EPA Office of Hazardous Materials, Wash. DC 20400.
CHRIS Manuals 1-4 (CG-446-1-4)	US Gov't Printing Office, Wash. DC 20402.
Regional Contingency Plan	US EPA-Regional Environmental Emergency Section.
Regulation for Shipping Hazardous Materials	
49 CFR-Code of Federal Regulations, Transportation Vol. 49 Pts. 170-189	US Dept. of Transportation Office of Hazardous Materials.
FAR 103-Federal Aviation Regulations Vol. VI Pt. 103	US Dept. Federal Aviation
CAB 82-Official Air Transport Restricted Articles Tariff No. 6-D	
IATA-International Air Transport Association Restricted Articles Regulations	
EPA Field Detection and Danger Assessment Manual for Oil and Hazardous Material Spills	US EPA Office of Water and Hazardous Materials Wash., DC 20400.
Official Motor Freight Directory	
Official Railway Guide	
Dangerous Properties of Industrial Materials, by N. Irving Sax	Van Nostrand Reinhold Co., 450 W. 33rd Street, New York, NY 10001
Chemical Transportation and Handling Guide	RSMA, 181 E. Lake Shore Drive, Chicago, IL 60611

TABLE 8. (continued)

Critical References	Critical Reference Source
Laboratory Waste Disposal Manual	Manufacturing Chemists Association, 1825 Connecticut Ave. N.W., Wash., DC 20009.
Recommended Methods of Reduction, Neutralization, Recovery or Disposal of Hazardous Waste (Vol. 1-16) by TRW Systems Group	NTIS US Dept. of Commerce Springfield, VA 22151.
Hazardous Chemicals Data	National Fire Protection Association 470 Atlanta Ave. Boston, MA 02110

Desirable References

Merck Index

Chemical Rubber Corporation, Handbook of Chemistry and Physics, CRC Press

Handbook of Chemistry - Handbook Publishers Inc. by NA Lange

Behavior of Organic Chemicals in the Aquatic Environment - Part I - A Literature Critique, Manufacturing Chemists' Association

Behavior of Organic Chemicals in the Aquatic Environment - Part II - Behavior in Dilute Solutions, Manufacturing Chemists' Association, April 1968

1963 Census of Manufacturers - Location of Manufacturing Plants by Industry, County, and Employment Size

Chemical Data Guide for Bulk Shipment by Water, US Coast Guard, 1966

Chemical Engineers' Handbook, Perry, John H., et al., eds., & 5th ed., 1973

Chemical Safety Data Sheets (SD-1 - SD-96), Manufacturing Chemists' Association

Handbook of Analytical Toxicology, Sunshine, I., ed., Chemical Rubber Co., 1969

MCA Chem-Card Manual

Mineral Facts and Problems, US Bureau of Mines Bull. 630, 1965

Organic Chemistry, Morrison, R.T., and R.N. Boyd, 2nd ed., 1966

Orsanco Quality Monitor, July 1970

Orsanco Quality Monitor, July 1970

The Pesticide Review, US Dept. of Agriculture, 1970

TABLE 8. (continued)

Desirable References

Hygienic Guide Series, American Industrial Hygiene Association

Pesticide Poisoning Of Pond Lake, Ohio, Investigation and Resolution (for the EPA, Ryckman, Edgerly, Tomlinson and Associates, Inc.

Proceedings of Conference On Hazardous Cargos, (US Coast Guard) July, 1970, New London, CT

Proceedings Of the 1972 National Conference On Control of Hazardous Material Spills (For the EPA) University of Houston, Houston, TX

Spill Prevention Techniques For Hazardous Polluting Substances, (For the EPA), Arthur D. Little Co.

Standard Methods For the Examination of Water and Wastewater, American Public Health Association, American Public Water Works, and Water Pollution Control Federation

Water Quality Criteria, McKee, J.E. and H. W. Wolf, The Resources Agency of California, State Water Quality Control Board

Water Quality Criteria - Report Of the National Technical Advisory Committee To the Secretary Of The Interior, April 1, 1968, F.W.P.C.A., Wash.

Pollution and Marine Ecology, Olson, T.A., and R.J. Burgess, 1967

Railroad Accident Report - Southern Railway Company Tranin 154 Derailment with Fire & Explosion, Laurel, MS., Jan. 25, 1969

Safety Guides (SG-1 - SG-19) Manufacturing Chemists' Association

Spillages of Hazardous Chemicals (Chart)

Water Pollution Abatement Manual, Manuals Sheets W-1, W-2, W-3, W-4 & W-6, Manufacturing Chemists' Association

Waterborne Commerce of the United States, US Corps of Engineers, Parts 1-5, 1968

Control of Spillage of Hazardous Polluting Substances, 15090 FOZ (for the EPA), Battelle Memorial Institute

Dangerous Articles Emergency Guide, Bureau of Explosives, Association of American Railroads

Explosives and Other Dangerous Articles, Bureau of Explosives, Association of American Railraods

Fire Protection For Chemicals, Bahme, C.W., National Fire Protection Association

3.0 - CHAPTER 3 - IDENTIFICATION AND ASSESSMENT

3.1 GENERAL

The information in this chapter deals with stepwise identification and assessment of the danger potential in a spill situation. The material presented has been divided into two parts which are directed at two people associated with the spill control effort. One person is called the Man on the Scene (MOS) who is the on-scene coordinator for the region or his designated representative at the spill site. The MOS is to provide information to a remote On-Scene Coordinator who has available to him the additional information critical to accurate spill identification and assessment. This Manual provides the remote OSC with directions for using information provided by the MOS and directing his further activity.

3.2 DIRECTIONS FOR THE MAN ON THE SCENE

3.2.1 Assumptions

There are various assumptions inherent in this presentation of the duties of the MOS. These assumptions include:

1. The Man on the Scene (MOS) is the on-scene coordinator or his designated representative at the site of a spill situation. The MOS is aware of the risks involved in spill control.

2. The responsibility of the MOS is to provide information to a remote OSC which will aid in spill identification and assessment of the human danger potential.

3. The responsibility for evacuation, fire fighting, or crowd control is not the duty of the appointed MOS but is assigned to other agencies, divisions, or personnel.

4. More than one person is available to perform the functions of the MOS, if necessary. Therefore, notification can be done concurrently with information gathering for identification.

3.2.2 Safety

The safety of the people who arrive on the scene of a hazardous spill is critical to consider before any action is taken. All spills are considered extremely hazardous. If the identity of the spill is not known, then the MOS should not approach the spill and should await the arrival of more highly trained, experienced personnel or a volunteer who is more aware of the risks involved with hazardous materials. In all cases, fully protective clothing should be worn by personnel at the spill site. In addition, the following general safety precautions should be followed:

1. Always approach a spill from upwind.

2. Don't touch the material and avoid any indirect or direct contact with it.

3. Remove all possible ignition sources. Do not smoke.

4. Restrict access to the area.

5. Do not touch any container unless full knowledge of the hazards involved is available.

6. If unidentified fuming liquids or gases are present, do not approach.

3.2.3 Identification Procedures - MOS

3.2.3.1 General - The MOS is the eyes and ears of a remote OSC. There are a series of steps to follow which will allow the MOS to specifically gather sufficient information for transfer to the OSC so an identification can be made.

3.2.3.2 Establish the type of soil - The first step is to determine what type of spill is involved by identifying the source of the spill. The following types of spills are possible:

a. Trains
   1. Tank car
   2. Box car

b. Trucks
   1. Tank
   2. Trailer

c. Bus

d. Aircraft
   1. Cargo
   2. Passenger

e. Ship
   1. Dry Cargo
   2. Tank Ship
   3. Com. Pass. Vessel
   4. Fishing Vessel
   5. CG Vessel
   6. Pleasure Craft
   7. Tugboat
   8. Unidentified

f. Barge

g. Pipeline
   1. Offshore
   2. On Shore

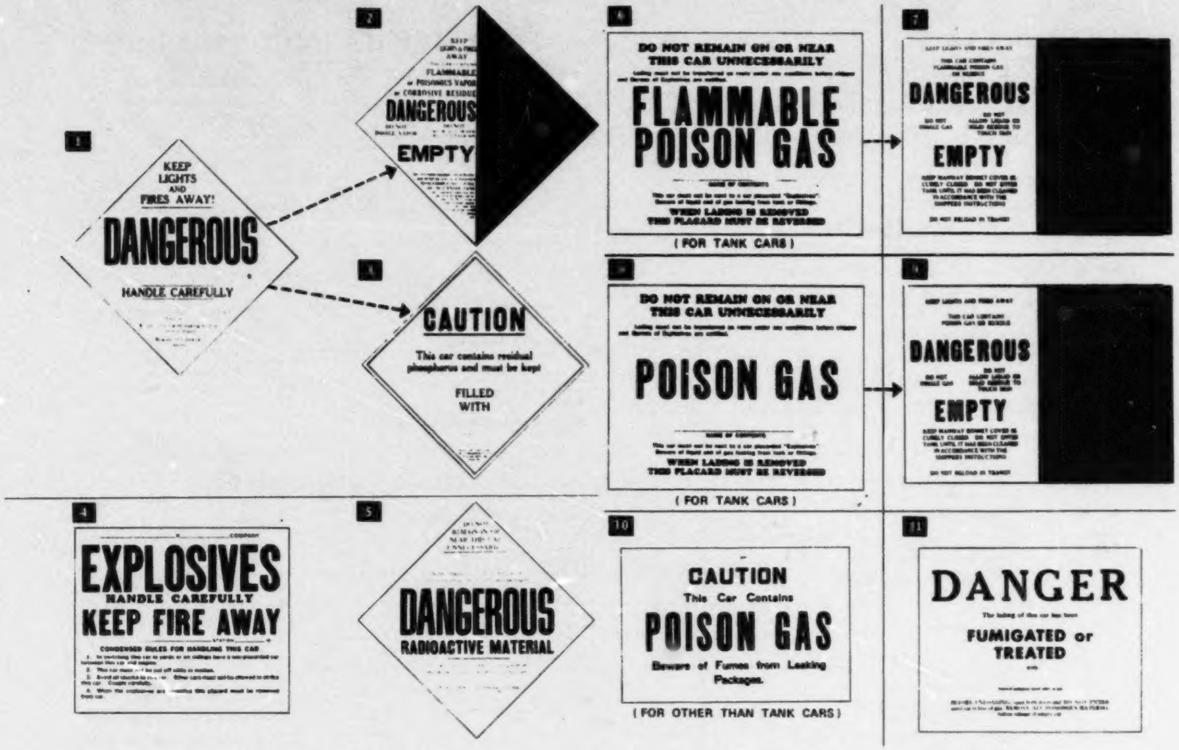
h. Storage Tank
   1. Offshore
   2. On Shore
   3. Other

Once the location and source of spill has been specified, the MOS should refer to the specific Figure (no. 2-12) which allows him to answer pertinent questions that lead to identification.

3.2.3.3 Notation of visible label - There are two types of package labels.(2) The MOS should answer the following questions if the packages can be safely investigated:

1. Are any warning labels visible?

1. Are any of the following hazardous placards or labels visible on the train car: (2)


1
KEEP LIGHTS AND FIRES AWAY!
DANGEROUS
HANDLE CAREFULLY
2
DANGEROUS
EMPTY
3
CAUTION
This car contains residual phosphorus and must be kept
FILLED WITH
6
DO NOT REMAIN ON OR NEAR THIS CAR UNNECESSARILY
FLAMMABLE POISON GAS
WHEN LADING IS REMOVED THIS PLACARD MUST BE REVERSED
(FOR TANK CARS)
7
DANGEROUS
EMPTY
8
DO NOT REMAIN ON OR NEAR THIS CAR UNNECESSARILY
POISON GAS
WHEN LADING IS REMOVED THIS PLACARD MUST BE REVERSED
(FOR TANK CARS)
9
DANGEROUS
EMPTY
4
EXPLOSIVES
HANDLE CAREFULLY
KEEP FIRE AWAY
5
DANGEROUS
RADIOACTIVE MATERIAL
10
CAUTION
This Car Contains
POISON GAS
Beware of Fumes from Leaking Packages.
(FOR OTHER THAN TANK CARS)
11
DANGER
FUMIGATED or TREATED

2. If so, what is the contents identification on the placard?
____

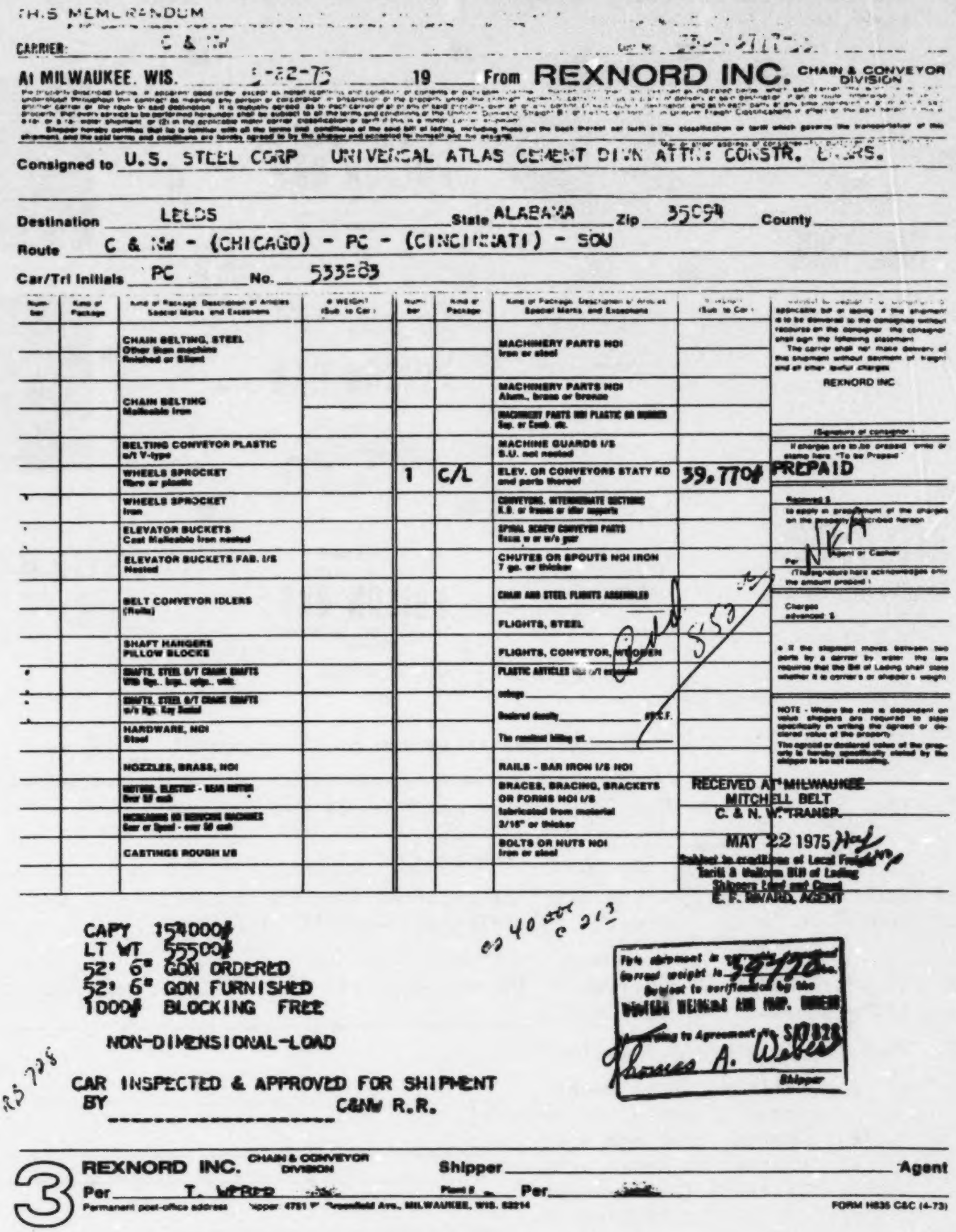
3. What is the identification, number and type of the car?
ID No. ____________
TYPE: Tank ____________ Boxcar ____________ Other ____________

4. Can the waybill (freight bill) be obtained from the conductor, in the engine or in the caboose? (3) (Typical waybill in Figure 3)
Yes ____________ No ____________

5. If yes, what is the office of the dispatcher? (Get information from train conductor if possible.) ____________________

6. What is the train's location?
   a. Railroad track owner ____________________
   (name on engine or caboose)
   b. Nearest town and distance ____________________
   c. Nearest railroad milepost ____________________
   d. Distance from nearest:
   Highway, and ____________________
   Highway number ____________________

Figure 2. Identification questions for train spills.



THIS MEMORANDUM

CARRIER: C & NW

At MILWAUKEE, WIS. 5-22-75 19 From **REXNORD INC.** CHAIN & CONVEYOR DIVISION

Consigned to U.S. STEEL CORP UNIVERSAL ATLAS CEMENT DIVN ATTN: CONSTR. ENGRS.

Destination LEEDS State ALABAMA Zip 35094 County

Route C & NW - (CHICAGO) - PC - (CINCINNATI) - SOU

Car/Trl Initials PC No. 533283

Number	Kind of Package	Kind of Package, Description of Articles, Special Marks and Exceptions	# WEIGHT (Sub. to Cor.)	Number	Kind of Package	Kind of Package, Description of Articles, Special Marks and Exceptions	# WEIGHT (Sub. to Cor.)
		CHAIN BELTING, STEEL Other than machine finished or Silent				MACHINERY PARTS NOI Iron or steel	
		CHAIN BELTING Malleable Iron				MACHINERY PARTS NOI Alum., brass or bronze	
						MACHINERY PARTS NOI PLASTIC OR RUBBER Sep. or Comb. etc.	
		BELTING CONVEYOR PLASTIC o/t V-type				MACHINE GUARDS I/S S.U. not nested	
		WHEELS SPROCKET fibre or plastic		1	C/L	ELEV. OR CONVEYORS STATY KD and parts thereof	39,770#
		WHEELS SPROCKET Iron				CONVEYORS, INTERMEDIATE SECTIONS K.D. or frames or idler supports	
		ELEVATOR BUCKETS Cast Malleable Iron nested				SPIRAL SCREW CONVEYOR PARTS [illegible] w or w/o gear	
		ELEVATOR BUCKETS FAB. I/S Nested				CHUTES OR SPOUTS NOI IRON 7 ga. or thicker	
		BELT CONVEYOR IDLERS (Rolls)				CHAIN AND STEEL FLIGHTS ASSEMBLED	
						FLIGHTS, STEEL	
		SHAFT HANGERS PILLOW BLOCKS				FLIGHTS, CONVEYOR, WOODEN	
		SHAFTS, STEEL O/T CRANK SHAFTS With [illegible]				PLASTIC ARTICLES [illegible] expanded	
		SHAFTS, STEEL O/T CRANK SHAFTS w/o [illegible] Key Seated				cubage ____ Declared density ____ P.C.F.	
		HARDWARE, NOI Steel				The resultant billing wt. ____	
		NOZZLES, BRASS, NOI				RAILS - BAR IRON I/S NOI	
		MOTORS, ELECTRIC - GEAR MOTOR Over 50 each				BRACES, BRACING, BRACKETS OR FORMS NOI I/S fabricated from material 3/16" or thicker	
		INCREASING OR REDUCING MACHINES Gear or Speed - over 50 each					
		CASTINGS ROUGH I/S				BOLTS OR NUTS NOI Iron or steel	

Paid 553

Subject to Section 7 of conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement: The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

REXNORD INC

(Signature of consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

PREPAID

Received $ to apply in prepayment of the charges on the property described hereon.

Per NKA Agent or Cashier

(The signature here acknowledges only the amount prepaid.)

Charges advanced $

• If the shipment moves between two ports by a carrier by water, the law requires that the Bill of Lading shall state whether it is carrier's or shipper's weight.

NOTE - Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.

The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding

RECEIVED AT MILWAUKEE
MITCHELL BELT
C. & N. W. TRANSP.
MAY 22 1975
Subject to conditions of Local Freight Tariff & Uniform Bill of Lading
Shippers Load and Count
E. F. [illegible], AGENT

CAPY 154000#
LT WT 55500#
52' 6" GON ORDERED
52' 6" GON FURNISHED
1000# BLOCKING FREE

NON-DIMENSIONAL-LOAD

CAR INSPECTED & APPROVED FOR SHIPMENT
BY ____________________ C&NW R.R.

40 c 213

This shipment is correctly described. Correct weight is 39770 lbs.
Subject to verification by the [illegible]
According to Agreement No. S17828
Thomas A. Weber
Shipper

RS 728

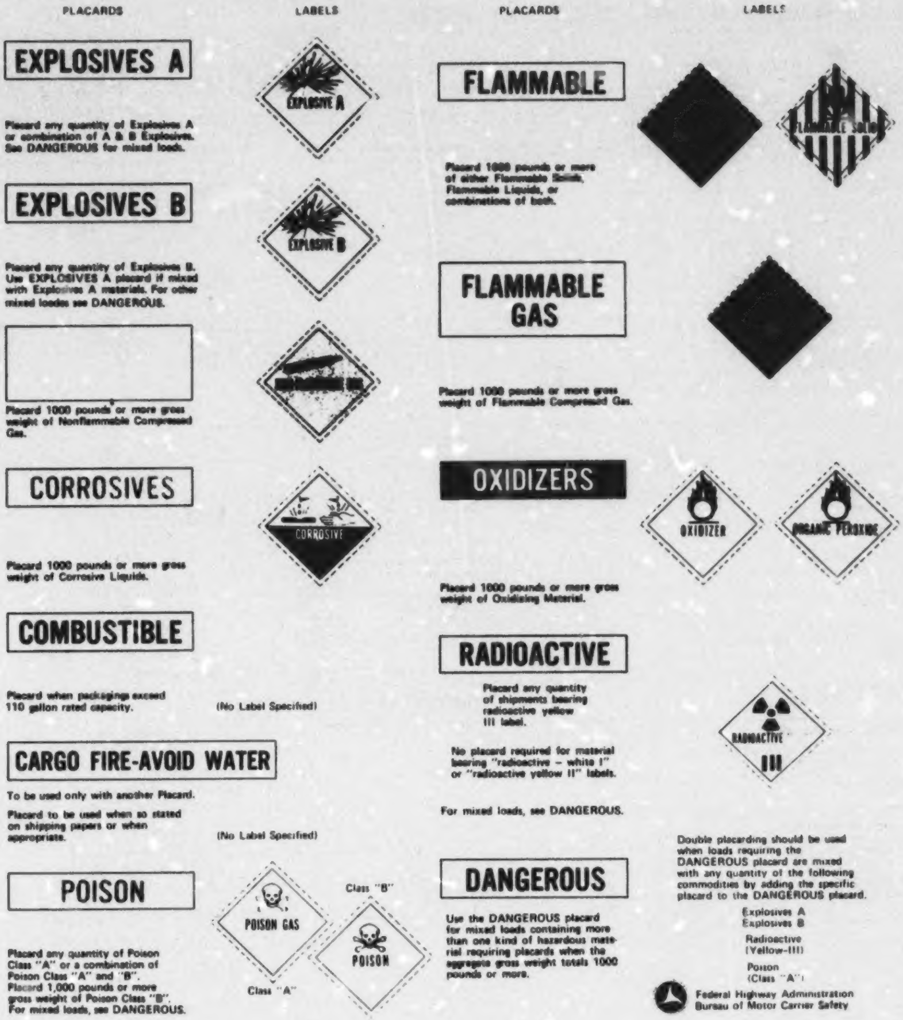
REXNORD INC. CHAIN & CONVEYOR DIVISION Shipper ____________ Agent
Per T. WEBER Plant # Per
Permanent post-office address of shipper: 4701 W. Greenfield Ave., MILWAUKEE, WIS. 53214

FORM H635 C&C (4-73)

Figure 3. Typical freight bill for rail shipment.

Reproduced from best available copy.

1. What Placards are visible? (2)



PLACARDS

LABELS

EXPLOSIVES A

Placard any quantity of Explosives A or combination of A & B Explosives. See DANGEROUS for mixed loads.

EXPLOSIVES B

Placard any quantity of Explosives B. Use EXPLOSIVES A placard if mixed with Explosives A materials. For other mixed loades see DANGEROUS.

Placard 1000 pounds or more gross weight of Nonflammable Compressed Gas.

CORROSIVES

Placard 1000 pounds or more gross weight of Corrosive Liquids.

COMBUSTIBLE

Placard when packagings exceed 110 gallon rated capacity.

(No Label Specified)

CARGO FIRE-AVOID WATER

To be used only with another Placard.

Placard to be used when so stated on shipping papers or when appropriate.

(No Label Specified)

POISON

Placard any quantity of Poison Class "A" or a combination of Poison Class "A" and "B". Placard 1,000 pounds or more gross weight of Poison Class "B". For mixed loads, see DANGEROUS.

Class "A"

Class "B"

PLACARDS

LABELS

FLAMMABLE

Placard 1000 pounds or more of either Flammable Solids, Flammable Liquids, or combinations of both.

FLAMMABLE GAS

Placard 1000 pounds or more gross weight of Flammable Compressed Gas.

OXIDIZERS

Placard 1000 pounds or more gross weight of Oxidizing Material.

RADIOACTIVE

Placard any quantity of shipments bearing radioactive yellow III label.

No placard required for material bearing "radioactive – white I" or "radioactive yellow II" labels.

For mixed loads, see DANGEROUS.

DANGEROUS

Use the DANGEROUS placard for mixed loads containing more than one kind of hazardous material requiring placards when the aggregate gross weight totals 1000 pounds or more.

Double placarding should be used when loads requiring the DANGEROUS placard are mixed with any quantity of the following commodities by adding the specific placard to the DANGEROUS placard.

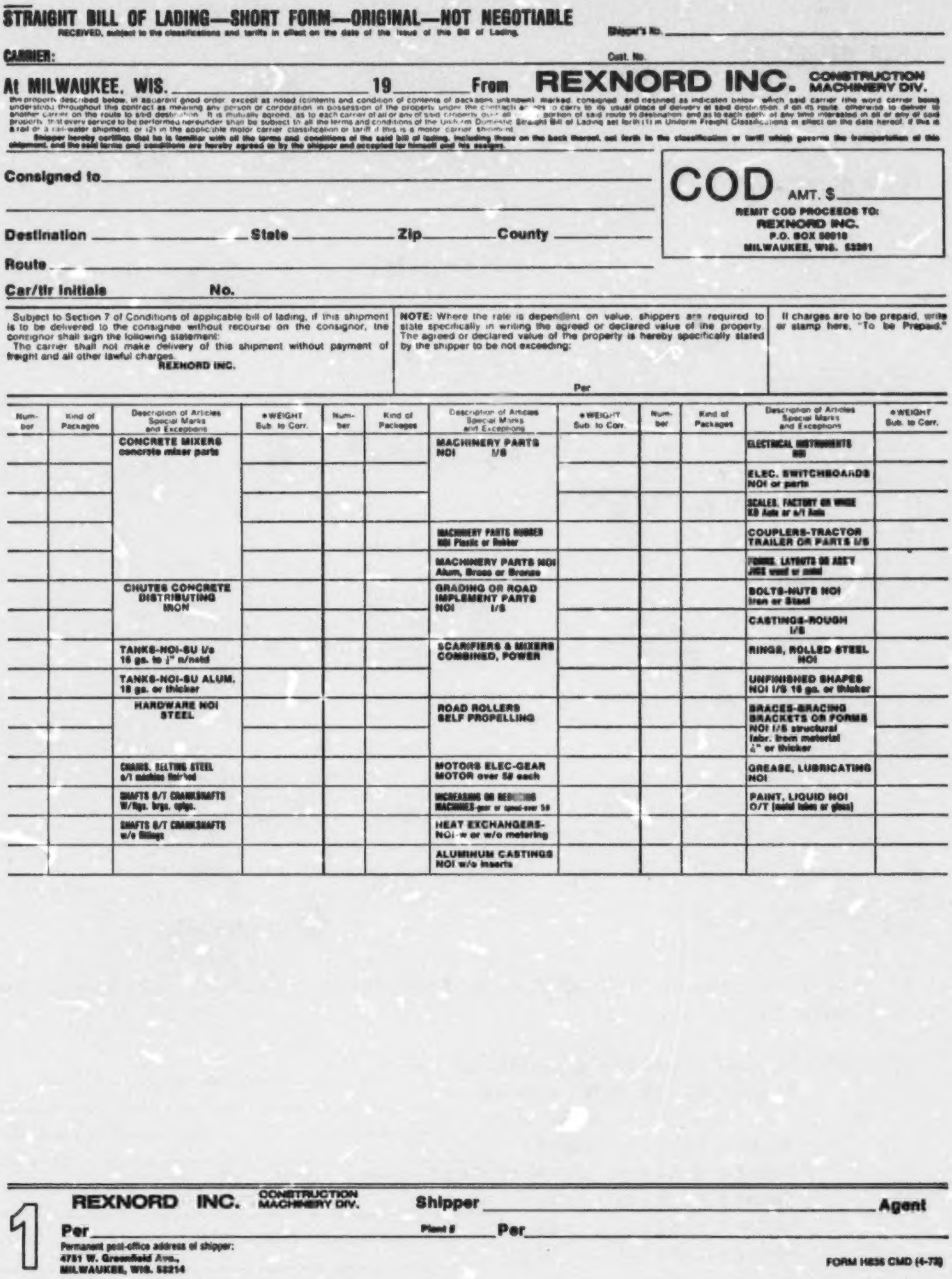
Explosives A
Explosives B
Radioactive
(Yellow-III)
Poison
(Class "A")

Federal Highway Administration
Bureau of Motor Carrier Safety

2. If possible, obtain bill of lading from driver (typical bill of lading in Figure 5).

3. If not: Record trucking company on cab ____________________
Record truck I.D. number ____________________
and type ____________________
Record highway number ____________________
Record distance from nearest town ____________________
Record highway market ____________________
Record distance from road ____________________
Record time of accident ____________________

Figure 4. Identification questions for truck spills.



STRAIGHT BILL OF LADING—SHORT FORM—ORIGINAL—NOT NEGOTIABLE

RECEIVED, subject to the classifications and tariffs in effect on the date of the issue of this Bill of Lading.

Shipper's No. ____________

CARRIER: ____________ Cust. No. ____________

At MILWAUKEE, WIS. ____________ 19 ______ From **REXNORD INC.** CONSTRUCTION MACHINERY DIV.

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Uniform Freight Classifications in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.

Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, including those on the back thereof, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

Consigned to ____________

Destination ____________ State ____________ Zip ______ County ____________

Route ____________

Car/tlr Initials ______ No. ____________

COD AMT. $ ______

REMIT COD PROCEEDS TO:
REXNORD INC.
P.O. BOX 50010
MILWAUKEE, WIS. 53201

Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement: The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges. REXNORD INC.	NOTE: Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property. The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding: Per	If charges are to be prepaid, write or stamp here, "To be Prepaid."

Number	Kind of Packages	Description of Articles Special Marks and Exceptions	*WEIGHT Sub. to Corr.	Number	Kind of Packages	Description of Articles Special Marks and Exceptions	*WEIGHT Sub. to Corr.	Number	Kind of Packages	Description of Articles Special Marks and Exceptions	*WEIGHT Sub. to Corr.
		CONCRETE MIXERS concrete mixer parts				MACHINERY PARTS NOI I/S				ELECTRICAL INSTRUMENTS NOI	
										ELEC. SWITCHBOARDS NOI or parts	
										SCALES, FACTORY OR WHSE KD Auto or n/t Auto	
						MACHINERY PARTS RUBBER NOI Plastic or Rubber				COUPLERS-TRACTOR TRAILER OR PARTS I/S	
						MACHINERY PARTS NOI Alum, Brass or Bronze				FORMS, LAYOUTS OR ASS'Y JIGS wood or metal	
		CHUTES CONCRETE DISTRIBUTING IRON				GRADING OR ROAD IMPLEMENT PARTS NOI I/S				BOLTS-NUTS NOI Iron or Steel	
										CASTINGS-ROUGH I/S	
		TANKS-NOI-SU I/s 16 ga. to ¼" n/nstd				SCARIFIERS & MIXERS COMBINED, POWER				RINGS, ROLLED STEEL NOI	
		TANKS-NOI-SU ALUM. 18 ga. or thicker								UNFINISHED SHAPES NOI I/S 16 ga. or thicker	
		HARDWARE NOI STEEL				ROAD ROLLERS SELF PROPELLING				BRACES-BRACING BRACKETS OR FORMS NOI I/S structural fabr. from material ¼" or thicker	
		CHAINS, BELTING STEEL o/t machine finished				MOTORS ELEC-GEAR MOTOR over 5# each				GREASE, LUBRICATING NOI	
		SHAFTS O/T CRANKSHAFTS W/fgs. brgs. cplgs.				INCREASING OR REDUCING MACHINES-gear or speed-over 5#				PAINT, LIQUID NOI O/T (metal tubes or glass)	
		SHAFTS O/T CRANKSHAFTS w/o fittings				HEAT EXCHANGERS-NOI-w or w/o metering					
						ALUMINUM CASTINGS NOI w/o inserts					

1

REXNORD INC. CONSTRUCTION MACHINERY DIV. Shipper ____________ Agent

Per ____________ Plant # ______ Per ____________

Permanent post-office address of shipper:
4751 W. Greenfield Ave.,
MILWAUKEE, WIS. 53214

FORM H835 CMD (4-73)

Figure 5. Typical truck bill of lading accompanying shipment.

1. Is a bus bill available from the driver? (typical bus bill in Figure 7)

   Yes ________

   No ________

2. If yes, obtain the bus bill from the driver.

3. If no, record:

   bus company ____________

   bus vehicle number ____________

   highway number ____________

   distance from nearest town ____________

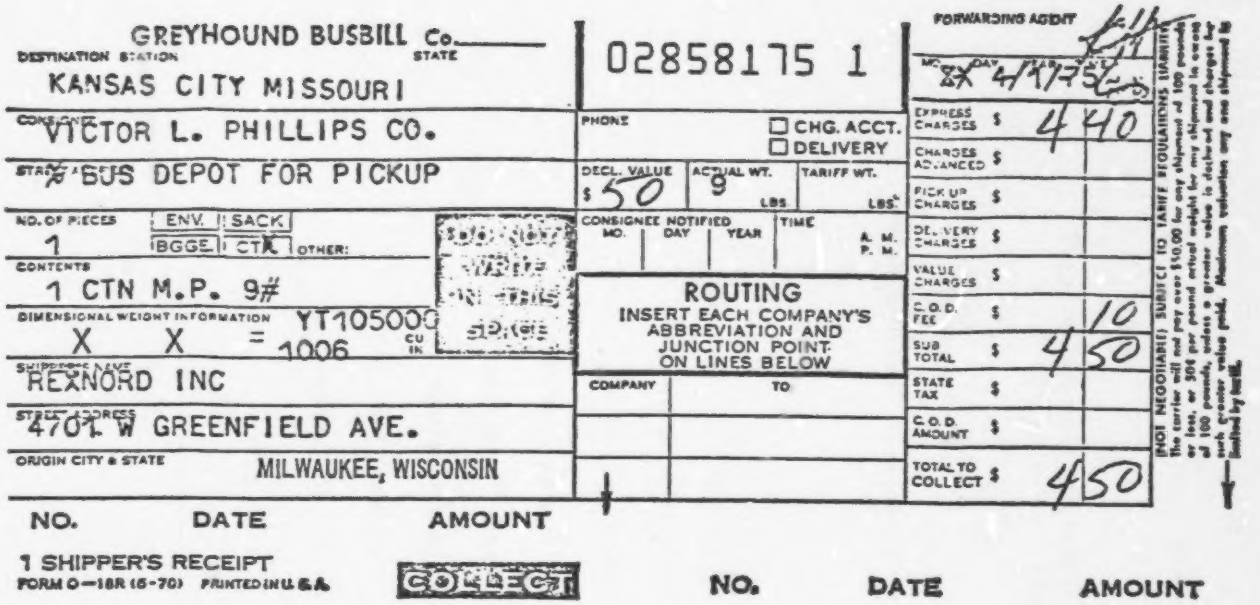
   name of nearest town ____________

   highway marker ____________

   distance from road ____________

   time of accident ____________

Figure 6. Identification questions for bus spills.



GREYHOUND BUSBILL Co.
DESTINATION STATION STATE
KANSAS CITY MISSOURI

CONSIGNEE VICTOR L. PHILLIPS CO.

STREET ADDRESS % BUS DEPOT FOR PICKUP

NO. OF PIECES 1 ENV. SACK BGGE. CTN X OTHER:

CONTENTS 1 CTN M.P. 9#

DIMENSIONAL WEIGHT INFORMATION X X = 1006 CU IN

YT105000

DO NOT WRITE IN THIS SPACE

SHIPPER'S NAME REXNORD INC

STREET ADDRESS 4701 W GREENFIELD AVE.

ORIGIN CITY & STATE MILWAUKEE, WISCONSIN

02858175 1

PHONE

☐ CHG. ACCT.
☐ DELIVERY

DECL. VALUE $ 50
ACTUAL WT. 9 LBS.
TARIFF WT. LBS.

CONSIGNEE NOTIFIED MO. DAY YEAR TIME A. M. P. M.

ROUTING
INSERT EACH COMPANY'S ABBREVIATION AND JUNCTION POINT ON LINES BELOW

COMPANY	TO

FORWARDING AGENT

MO. DAY YEAR 4/17/75

EXPRESS CHARGES	$	4	40
CHARGES ADVANCED	$		
PICK UP CHARGES	$		
DELIVERY CHARGES	$		
VALUE CHARGES	$		
C.O.D. FEE	$		10
SUB TOTAL	$	4	50
STATE TAX	$		
C.O.D. AMOUNT	$		
TOTAL TO COLLECT	$	4	50

(NOT NEGOTIABLE) SUBJECT TO TARIFF REGULATIONS LIABILITY The carrier will not pay over $50.00 for any shipment of 100 pounds or less, or 50¢ per pound actual weight for any shipment in excess of 100 pounds, unless a greater value is declared and charges for such greater value paid. Maximum valuation any one shipment is limited by tariff.

NO. DATE AMOUNT

1 SHIPPER'S RECEIPT
FORM O—18R (5-70) PRINTED IN U.S.A.

COLLECT

NO. DATE AMOUNT

Figure 7. Typical bus bill attached to package .

Reproduced from best available copy.

1. Are the shipping papers available from the captain of the ship?

   Yes ______ No ______

2. If yes, obtain papers from the captain.

3. If no,

   1. What is the ship's flag configuration?

      ____

      ____

      ____

      ____

   2. Record the vessel Name ______________

      Number ______________

      Nationality ______________

   3. Location:

      Name of nearest city ______________

      Distance from nearest city ______________

      Water body involved ______________

      Distance from shore ______________

Figure 8. Identification questions for spills from marine vessels.

1. What warning placards are visible?

   a. Warning
   b. Dangerous Cargo
   c. No Visitors - indicates possible poisonous cargo
   d. No Smoking
   e. No Open Lights
   f. Other ______________________________
   g. None

(These placards are generally 3 feet x 2 feet with black letters on a white background.)

2. Does the barge captain have the shipping papers?

   Yes ___________ No ___________

3. If yes, obtain these papers.

4. If no, record:

   Barge Name ___________________________
   Barge Number ___________________________
   Name of Waterway ___________________________
   Distance from Shore ___________________________
   Name of Nearest City ___________________________
   Distance from Nearest City ___________________________

Figure 9. Identification questions for spills from barges.

1. Does the pilot have the shipping papers? (4)

Yes ___________ No ___________

2. If yes, obtain these papers.

3. If no, record:

Airline of Plane ______________________
Number of Plane ______________________
Number of Nearest Highway ______________________
Highway Marker ______________________
Distance from Highway ______________________
Name of Nearest Town ______________________
Distance from Nearest Town ______________________
Time of Accident ______________________

Figure 10. Identification questions for spills from airplanes

1. Is a pipeline marker available?

2. If yes, record all information from marker.

____

3. If no, record:

Name of Pipeline owner (if available) ______________
Nearest Highway Number ______________________
Distance from Highway ______________________
Highway Mile Marker ______________________
Nearest Town ______________________
Distance from Nearest Town ______________________
Time of Spill ______________________

Figure 11. Identification questions for spills from pipleines

1. Is an identification plate attached to the tank?

Yes __________ No __________

2. If yes, copy information: ______________________________

____

3. If no, record:

Address of spill by nearest streets ____________________

Time of spill ____________________

4. Are any additional coding systems visible? For example:

If gas cylinders are involved, what is the color of the cylinder? ______________________________

And, what is the name of the distributor? ______________

____

If chemicals are used, what is the color of the cap?

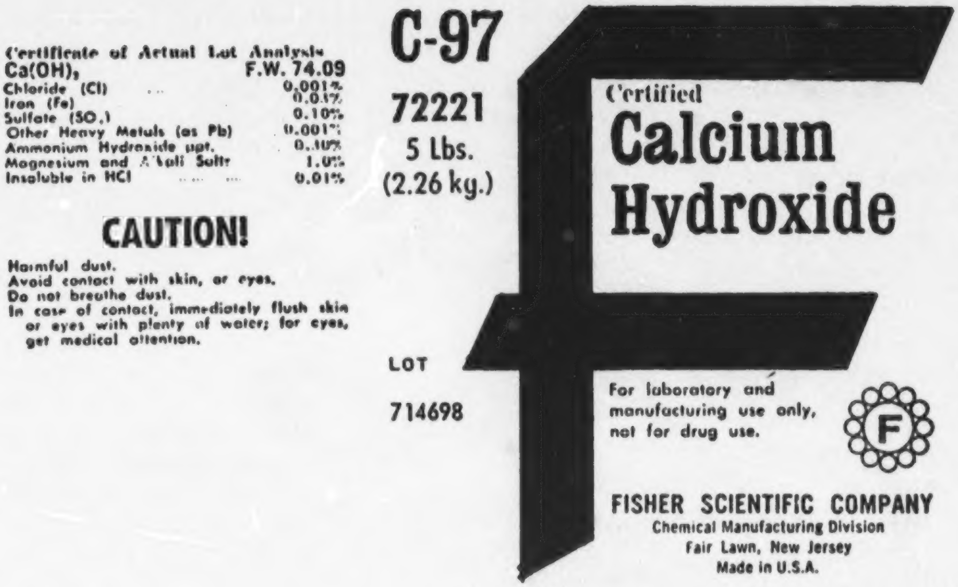
______________ or printing ____________________

and what is the name of the distributor ______________

____

Figure 12. Identification questions for spills from storage tanks

2. Are any identifying labels visible? (An example appears in Figure 13).



Certificate of Actual Lot Analysis

$Ca(OH)_2$	F.W. 74.09
Chloride (Cl)	0.001%
Iron (Fe)	0.01%
Sulfate (SO_4)	0.10%
Other Heavy Metals (as Pb)	0.001%
Ammonium Hydroxide ppt.	0.10%
Magnesium and Alkali Salts	1.0%
Insoluble in HCl	0.01%

CAUTION!

Harmful dust.
Avoid contact with skin, or eyes.
Do not breathe dust.
In case of contact, immediately flush skin or eyes with plenty of water; for eyes, get medical attention.

C-97

72221

5 Lbs.
(2.26 kg.)

Certified

Calcium Hydroxide

LOT

714698

For laboratory and manufacturing use only, not for drug use.

FISHER SCIENTIFIC COMPANY
Chemical Manufacturing Division
Fair Lawn, New Jersey
Made in U.S.A.

Figure 13. Typical chemical packaging label.

3.2.3.4 Record easily visible physical properties - Observation of the following properties of the spilled material can confirm an identification or possibly identify the specific chemical involved (5). However, the MOS must approach the spill cautiously and not endanger himself and others in determining the characteristics. If a certain physical property cannot be readily identified, do not answer that question and go on to the next one.

1. What state is the spill:
   1. Solid (powder, pellet, granular)
   2. Liquid
   3. Gas

2. Is there a noticeable odor from a safe distance?

   Pleasant - almond, ammonia, benzene, fragrant, lysol, vinegar, sweet

   Unpleasant - sulfur, irritant, foul, skunk, onion, sharp, biting, mothball, cleaning fluid, paint

3. What color is it?

4. Is it turbid?
   - Opaque -
   - Clear -
   - Cloudy -
   - Other -

5. If it is in water, does it
   - float
   - sink
   - mix (soluble)
   - remain unmixed

6. Does it cause your eyes to water?
   - Yes
   - No

7. Is it
   - fuming
   - flaming
   - foaming
   - or is a gas being given off
   - or is another noticeable reaction occurring

3.2.3.5 Contact the OSC - Once this information has been assembled, the OSC should be contacted. The information can be transmitted to the OSC who will then direct the MOS to perform additional steps to aid in identification or will direct him to begin to assess the danger potential of the situation.

3.2.3.6 Further steps for identification - If so directed by the OSC the MOS can take one or more of the following steps to aid in specific identification of the spilled material:

1. Make on-site inspections to determine which cargo is damaged and undamaged:

This procedure requires the MOS to be very cautious and board the vehicle to check the cargo. The procedure is only required for mixed loads and will allow elimination of various cargoes which have not been damaged from the list of possible materials involved in the spill.

2. Take samples for chemical testing: The OSC may direct the MOS to collect samples and then ship or deliver these samples to a specified laboratory. Care must be taken at all times to protect the MOS. The spill should not be approached without fully protective clothing.

3.2.4 Assessment of Spill Magnitude and Human Danger Potential by the MOS

3.2.4.1. General - Once the spill has been identified as to its specific constituents, the magnitude of the spill and its potential danger to human safety must be established. To determine this, the MOS must answer a series of questions which pertain to the spill situation. The OSC can then establish the effect of the spill using various references.

3.2.4.2 Magnitude of the spill - The MOS can gather the needed information regarding the spill to give to the OSC by answering the following questions:

1. Note the label information, if available.

2. What type and size of individual containers have spilled the material?

    1. Metal drums approx. height ______________
    diameter______________

    2. Fiber drums approx. height ______________
    diameter______________

    3. Bags
    Paper Length ________ Width______ Height_____
    Polyethylene Length________ Width______ Height_____

    4. Cylinders Length________ Width______ Height_____

    5. Carboys Diameter________ Height______

    6. Boxes Type Length________ Width______ Height______

    7. Other Dimensions

3. How many of each type of container have been spilled?

4. If large tank trucks or cars or barge and ship holds are involved, the approximate size can be estimated by pacing off

a similar distance at a remote location.

Size____________ X________________ X________________

Often the tank cars and trains are labeled so the capacity should be recorded ___________________

3.2.4.3 Human Danger Potential - Information regarding environmental conditions and location of the spill is necessary to determine the danger which exists from the spill itself. There are various questions which must be answered by the MOS and then this information transferred to the OSC.

1. What time did the discharge start, ____________________________
   Determine this information by questioning eyewitnesses to the spill.
2. Where is the discharge occurring? (ie. location of spill) The same information is required as was indicated in the identification section. Necessary information for each spill source is summarized in Table 9.

Table 9. METHODS OF IDENTIFYING SPILL LOCATION

Transportation Mode	Method
Train	Railroad track owner/nearest town (name and distance) railroad track milepost (alternate as for trucks)
Truck	Highway name/highway number/nearest town (name and distance)/distance from road
Bus	Same as for truck
Airplane	Distance and direction from highway/location on highway as for truck
Ship	Name of waterway/nearest coastline/distance and direction from shore/location & name of nearest town
Barge	Same as for ship
Pipeline	Pipeline marker or distance and direction from highway/location on highway as for truck
Storage Tank	Address in relation to nearby streets, distance and direction from highway/location on highway as for truck.

3. How close is the spill to populated areas?__________________
4. What is the spill affecting?
   a. In water

b. On land

c. In air

d. Combination (indicate which)

5. Are any water intakes or wells in the near vicinity? ________

6. What is the rate of discharge? ____________________

7. This rate can be estimated by noting indirect factors including:

   a. What is the shape or type of hole or leak?

      Triangular hole____________________

      Rectangular hole___________________

      Split seam________________________

      Valve leak ________________________

      Puncture _________________________

      Breakage _________________________

   b. How high is the liquid above hole/water? (If in water)

   c. Is the hull listing? (Ship or barge)

   d. How much material is left in the tank? (Approximately 1/2, 1/4, etc.)

   e. If the source of the spill can be safely approached, the rate can be estimated by measuring depth differences and the area of the tank measured as follows: (6)

      1. Determine the length and width of the leaking tank. length____ width____

      2. Stick a long, straight pole (gage pole) or "dipstick" down into the tank either through an "ullage" hole, or through a hatch cover, pull it up, note what time it is, and measure the length of the pole which is "wet". time (1)____ length(1)____

      3. Wait 15 minutes or so if the leak is slow, or a shorter period of time if it is relatively fast. time (2)__________

      4. Repeat step 2 above. length (2)_________

   f. If stopped, how long did the discharge last?___________

8. How much area is affected by the spill?

Land: Pace off the length and width of the affected area from a remote similar distance and record.

length ______________ width ______________

Water: a. Indicate the type of water body affected.

Ocean / River / Lake / Bay / Harbor / Stream / Swamp

(Other) ____

b. Estimate the size of the water body. Pace off the affected distances from shore or use Figure 14 to estimate stream width.

Stream Width (feet)		Stream Width (feet)	
0-75	____________	1200-1800	____________
75-200	____________	1800-2200	____________
200-400	____________	2200-2800	____________
400-800	____________	2800-3400	____________
800-1200	____________	greater than 3400	______

ft x 0.305 = m

Figure 14 Estimating Stream Widths (6)

c. Estimate the flow rate if any. Use the following procedure:

1. Measure a straight distance along length of water body. length_______________
2. Drop floating object into water and record time time___(1)_____________
3. Record time when object reaches end of measured length time (2) __________
4. Current speed in ft/sec (ft/sec x 0.305 = m/sec)

$$0.8 \left[\frac{\text{length (ft)}}{\text{time 2 - time 1 (sec)}} \right] \quad (7)$$

d. Estimate direction of flow (N., S., E., W., etc.)

e. Estimate depth of waterway. If accessible use a stick plunged straight into the bottom and measure wet level as a depth. Measure in the middle of a stream if possible.

If direct measurement is impossible, use topographical maps of the area to establisn depths.

f. Estimate depth of water near point of discharge. ____________________
The stick technique is best, if access is possible. If not, choose a similar configuration upstream of the spill and measure that depth.

g. If a gas spill is occurring:

   a. What is the approximate diameter of the hole in the cylinder? ____________

   b. Is a vapor cloud visible? Yes
      No

   c. If yes, is the cloud rising
      lying on ground
      other__________

9. Is a pool of liquid visible on land or on the water?

10. Where is the leak originating?

Barge	Type	Size
Ship	Type	______Size
Tank Truck	Type	Size
Train Tank Car		Size
Airplane Hull		Size
Individual container	Type	
Pipeline		Diameter
Storage tank	______Diameter	______Height

11. What is the condition of the source?

    Repairable leak
    Uncontrollable leak
    Easily moved
    Unmovable
    Other

3.2.4.4 Meteorological Conditions - Information regarding the weather conditions is also important in assessing the potential danger of a spill. The MOS can also answer the following questions:

1. What is the wind speed and direction? The wind speed can be estimated using the Beaufort scale. (Figure 15)
   The wind direction is that direction from which the wind is blowing and observation of a lightweight object will give this information.

	Wind Speed		Hydrographic Office	International	Estimating Wind Speed	
Beaufort number	Knots	mph	Term and height of waves, in feet	Term and height of waves, in feet	Effects observed at sea	Effects observed on land
0	under 1	under 1	Calm, 0		See like mirror	Calm: smoke rises vertically
1	1-3	1-3	Smooth, less than 1	Calm, glassy, 0	Ripples with appearance of scales, no foam crests	Smoke drift indicates wind direction; vanes do not move.
2	4-6	4-7	Slight, 1-3	Rippled, 0-1	Small wavelets; crests of glassy appearance, not breaking	Wind felt on face; leaves rustle; vanes begin to move.
3	7-10	8-12	Moderate, 3-5	Smooth, 1-2	Large wavelets; crests begin to break; scattered whitecaps.	Leaves, small twigs in constant motion; light flags extended.
4	11-16	13-18		Slight, 2-4	Small waves, becoming longer; numerous whitecaps.	Dust, leaves, and loose paper raised up; small branches move
5	17-21	19-24	Rough, 5-8	Moderate, 4-8	Moderate waves, taking longer form; many whitecaps; some spray.	Small trees in leaf begin to sway.
6	22-27	25-31		Rough, 8-13	Larger waves forming; whitecaps everywhere; more spray.	Larger branches of trees in motion, whistling heard in wires.
7	28-33	32-38			See heaps up; white foam from breaking waves begins to be blown in streaks.	Whole trees in motion, resistance felt in walking against wind.
8	34-40	39-46	Very rough, 8-12	Very rough, 13-20	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well marked streaks.	Twigs and small branches broken off trees; progress generally impeded.
9	41-47	47-54	High, 12-20		High waves; sea begins to roll; dense streaks to foam; spray may reduce visibility.	Slight structural damage occurs; slate blown from roofs.
10	48-55	55-63	Very high, 20-40	High, 20-30	Very high waves with overhanging crests; sea takes white appearance as foam is blown in very dense streaks; rolling is heavy and visibility reduced.	Seldom experienced on land; trees broken or uprooted; consideralbe structural damage occurs.
11	56-63	64-72	Mountainous, 40 and higher	Very high, 30-45	Exceptionally high waves; sea covered with white foam patches; visibility still more reduced.	Very rarely experienced on land; usually accompanied by widespread damage

Knots x 1.185 = km/hr mph x 1.61 = km/hr ft x 0.305 =

Figure 15. Beaufort scale for wind speed estimation.

2. What are the weather conditions?

   ie. Temperature of air ____________
   humidity of air ____________
   percentage of sky which is cloudy ____________
   weather conditions ____________
   rainy ____________
   snowy ____________
   dry ____________
   humid ____________

   This information can be obtained by direct observation and the weather bureau reports.

3. What is the weather forecast?
   This information is important especially when precipitation is expected and it can be determined from weather bureau reports.

   Weather forecast ________________________________
   ____
   ____

3.3 DIRECTIONS FOR THE OSC

3.3.1 Assumptions

There are two assumptions basic to this section regarding the OSC:

1. The OSC has experience in handling a spill situation and will give immediate information or instructions over the phone 24 hours/day.
2. The OSC has many spill response references available including those listed in Table 8.

In addition, the OSC will have direct access to other reference material at the Regional Response Center.

3.3.2 Identification

3.3.2.1 General - The OSC will use the information relayed to him from the MOS and apply his experience and resources to establish a positive identification of the material involved. This identification process may require only one or two steps plus confirming identification by physical properties or it may require lengthy phone calls and searches. The following paragraphs discuss the possible procedures which can be followed.

3.3.2.2 Step 1 - Collect Information From MOS - The OSC first must assimilate the MOS information. The answer is placed on sheets identical to those the MOS has completed, Sections 3.2.3.2-3.2.3.4.

Then the OSC can begin to use the information.

3.3.2.3. Step 2 - Identification From Shipping Papers - If papers are available with the vehicle, the process of identification is as follows:

Determine if a multiple or single load is involved.

a. If a single load is being shipped, the identification is almost complete but the shipping company should be contacted for confirmation.

b. If multiple loads are involved, a further study is needed. First, study the list of materials from the freight bill and then investigate the following possibilities.

    1. Is an extremely posisonous gas involved?

    2. Is a flammable or explosive material involved?

    3. Are incompatible chemicals on the same vehicle? (See Table 10)

However, the chart should not be used as an infallible guide. It should only provide general guidelines regarding chemical incompatibility. An expert should be consulted regarding any known mixture and the potential compatibility confirmed.

If the situation is not safe for a close investigation, the OSC must require identification by physical properties or sampling. (See Section 3.2.3.6.) However, if the MOS can enter the vehicle and check the cargo for damaged and undamaged containers, this should be done. Then the specific hazard may be identified.

However, if shipping papers are not available or are not available in readable form, the OSC must obtain a copy of the papers or expert advice regarding the information. Table 11 summarizes the knowledge necessary for obtaining copies of the material involved. The reference will indicate telephone number of the shipping company and the Vice President in charge of operations must be contacted. If it is not working hours, the police in that city may be able to contact the person needed.

Usually copies are available at the origin of the shipment with the manufacturer and possibly with the company receiving the material. The copy at the shipment origin (ie. loading location) is generally the easiest to obtain.

3.3.2.4 Step 3 - Identification Using Placards and Labels - If the shipping papers are not immediately available, labels and placards can be used to indicate the hazard involved. Extreme caution must be used and care should be taken to insure that correct information has been gathered. The two general types of information are available as warning placards or labels and specific identification labels.

TABLE 10. COMPATIBILITY CHART TAKEN FROM CHRIS CG-446-1 (8)

1	Inorganic Acids	1																							
2	Organic Acids	X	2																						
3	Caustics	X	X	3																					
4	Amines & Alkanolamines	X	X		4																				
5	Halogenated Compounds	X		X	X	5																			
6	Alcohols, Glycols & Glycol Ethers	X					6																		
7	Aldehydes	X	X	X	X		X	7																	
8	Ketones	X		X	X			X	8																
9	Saturated Hydrocarbons									9															
10	Aromatic Hydrocarbons	X									10														
11	Olefins	X				X						11													
12	Petroleum Oils												12												
13	Esters	X		X	X									13											
14	Monomers & Polymerizable Esters	X	X	X	X	X	X								14										
15	Phenols			X	X			X							X	15									
16	Alkylene Oxides	X	X	X	X		X	X							X	X	16								
17	Cyanohydrins	X	X	X	X	X		X									X	17							
18	Nitriles	X	X	X	X												X		18						
19	Ammonia	X	X					X	X					X	X	X	X	X		19					
20	Halogens			X			X	X	X	X	X	X	X	X	X	X				X	20				
21	Ethers	X													X						X	21			
22	Phosphorus, Elemental	X	X	X																	X		22		
23	Sulfur, Molten									X	X	X	X				X						X	23	
24	Acid Anhydrides	X		X	X		X	X							X		X	X	X	X					24

X Represents unsafe combinations.

The following pages list the chemicals by chemical name and by reactivity groups. Obtain the group for the chemical and then read chart, first from left to right, then down.

Chemicals Not On Chart

Carbon Bisulfide forms an unsafe combination with reactivity groups 1, 4, 19, 20, and epichlorohydrin.

Epichlorohydrin forms an unsafe combination with reactivity groups 1, 2, 3, 4, 14, 15, 19, 20, 22, 23, 24, and carbon bisulfide.

Motor Fuel antiknock compounds form unsafe combinations with reactivity groups 1, 4, 5, 6, 7, 15, 19, and 20.

TABLE 10. (continued)

Procedure for use of compatibility chart (8)

1. Determine the reactivity of the product by reference to CHRIS (CG-446-1).

2. Enter the Chart with the reactivity group. Proceed across the page. An "X" indicates a reactivity group which forms an unsafe combination with the product in question

3. At the end of the line, proceed downard. An "X" again indicates groups that form unsafe combinations.

REMEMBER that this chart is only a guide, further confirmation should be obtained before assuming the condition is safe. See CG-446-1, A Condensed Guide to Chemical Hazards, page 7-1 to 7-14 for additional information.

Table 11. SUMMARY ON HOW TO OBTAIN SHIPPING PAPER COPIES

Type of Vehicle	Information required	Reference
Truck	Cab number Trailer number Name trucking company Location and time of truck spill	Official Motor Freight Directory
Train	Car number Name of railroad (from engine or caboose)	Official Railway Guide
Bus	Bus number Name of bus company Location and time of bus spill	Call Bus Company (Yellow Pages)
Ships	Signal flag Vessel name and number Location and time of ship spill	Merchant Vessels of the U.S. U.S. Army Corp of Engineers Ship I.D. book
Barges	Barge name and number Location and time of spill	Call nearest Harbor or Port Commission for reference
Airplane	Airplane number and name (if any) Airlines Location and time of spill	Nearest Airport and the name of the airlines

The placards are usually general and indicate only hazards rather than specific identities. The materials which require these placards are listed in DOT regulations 49CFR and identities can be confirmed using this cross reference. However, mixtures or small amounts of materials are not clearly placarded and, therefore, the lack of a placard or a "dangerous" warning may be misleading.

Labels are of two types: warning and identification. The required warning labels are also listed in DOT 49CFR (2) and the types are shown in Figure 16. As with placards, the information is of a general nature and does not specifically identify the chemical. On the other hand, individual chemical labels (See Figure 13) provide specific information and identity of the chemical involved.

To determine information from labels, the OSC must direct the MOS to closely examine the cargo if this action can be safely accomplished. The information, carefully recorded, can then be relayed to the OSC for identification.

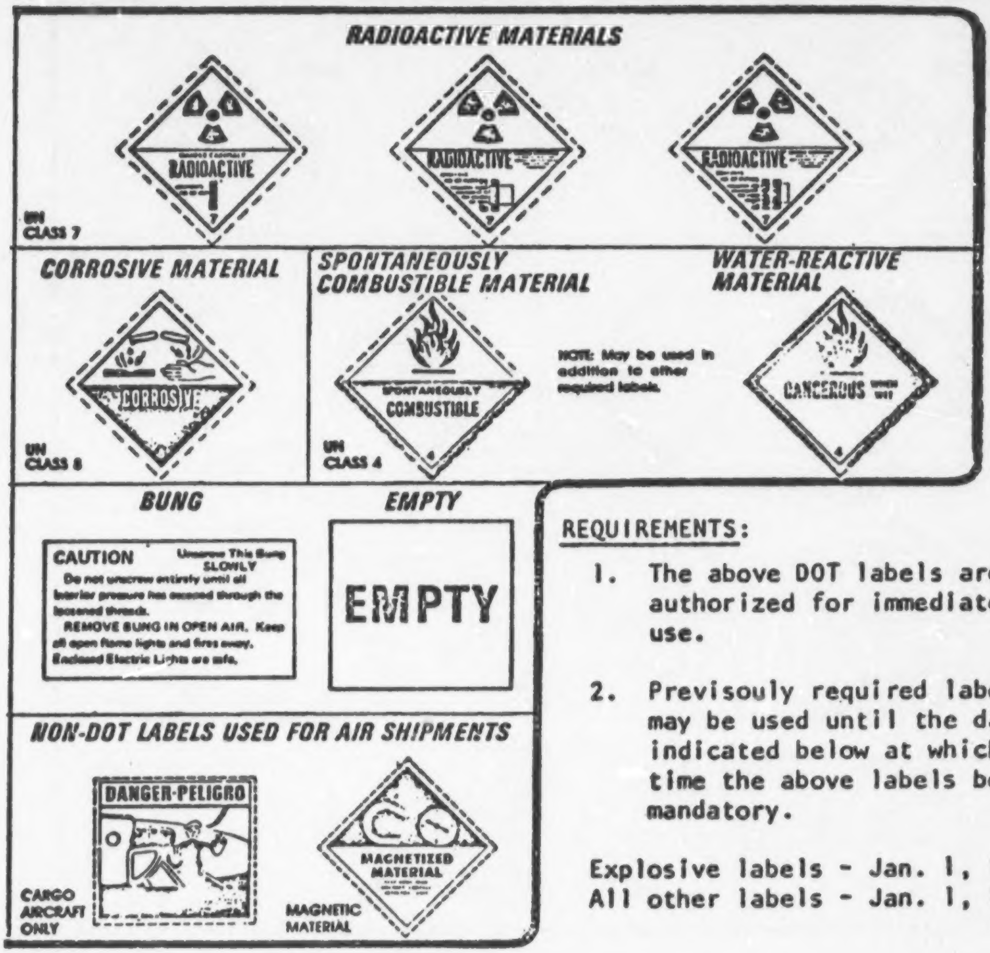
3.3.2.5 Step 4 - Identification Using Miscellaneous Aides - In addition to the shipping papers and placards, other information is also available. One of the most helpful are the Chemcards recommended and produced by the Manufacturing Chemists Association. The information on the Chemcards includes (9):

Identification of the cargo
Appearance and odor
Statement of hazards involved and instructions for safe handling and, as applicable, the need for special cargo environments
Emergency procedures and precautions
Fire fighting procedures and precautions

However, if mixed loads of hazardous materials are involved, further identification steps are necessary.

Another aid to the OSC is a requirement by the Coast Guard that all foreign vessels carrying hazardous materials register the intended route of the ship with the nearest Captain of the Port Coast Guard Office. Also, all vessels carrying any of the 40 specified dangerous cargoes (See Table 12) must notify the Captain of the Port at least 24 hours prior to arrival. Therefore, when ships are the source of a spill, more detailed information can be obtained from the Coast Guard.

3.3.2.6 Step 5 - Identification Through Physical Properties - If there is no direct information available from shipping papers or other sources, the physical properties can aid in establishing the identity of the material involved. These properties are also


RADIOACTIVE MATERIALS
RADIOACTIVE
RADIOACTIVE
RADIOACTIVE
UN CLASS 7
CORROSIVE MATERIAL
CORROSIVE
UN CLASS 8
SPONTANEOUSLY COMBUSTIBLE MATERIAL
SPONTANEOUSLY COMBUSTIBLE
UN CLASS 4
WATER-REACTIVE MATERIAL
NOTE: May be used in addition to other required labels.
DANGEROUS WHEN WET
BUNG
CAUTION
Unscrew This Bung SLOWLY
Do not unscrew entirely until all interior pressure has escaped through the loosened threads.
REMOVE BUNG IN OPEN AIR. Keep all open flame lights and fires away. Enclosed Electric Lights are safe.
EMPTY
EMPTY
NON-DOT LABELS USED FOR AIR SHIPMENTS
DANGER-PELIGRO
CARGO AIRCRAFT ONLY
MAGNETIZED MATERIAL
MAGNETIC MATERIAL

REQUIREMENTS:

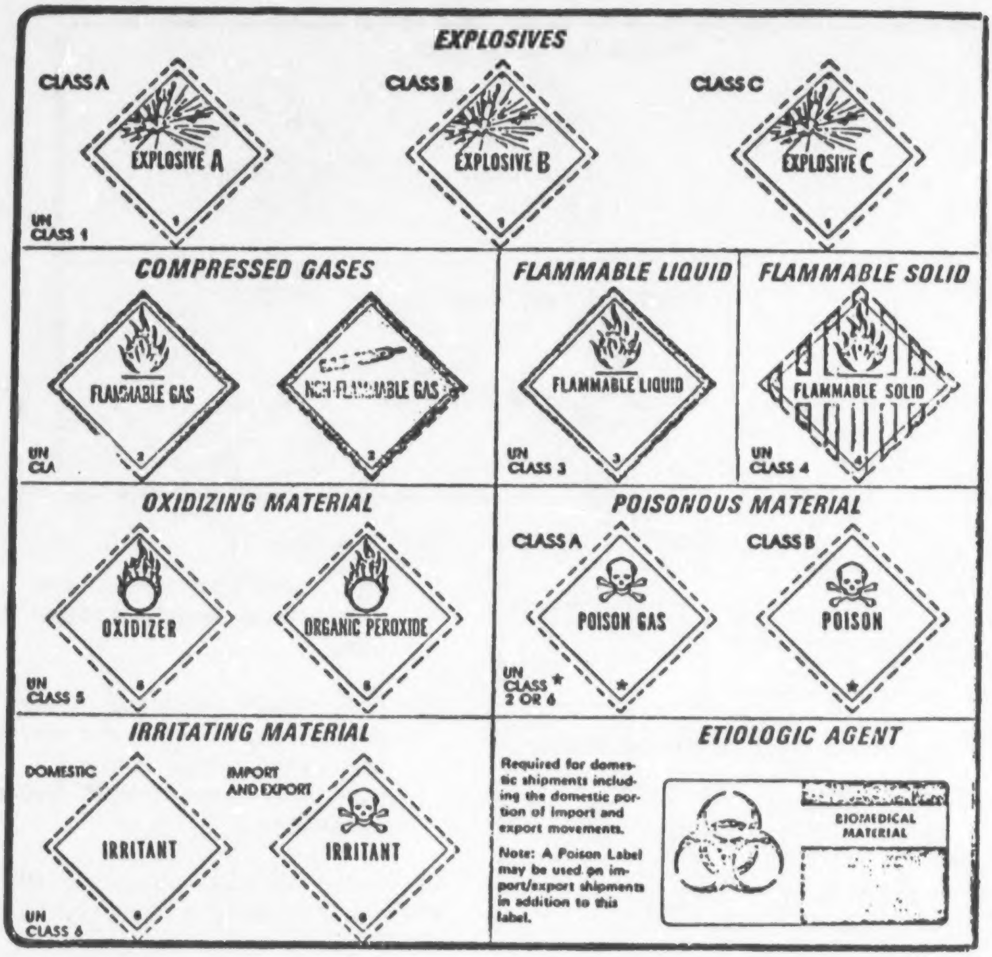
1. The above DOT labels are authorized for immediate use.

2. Previsouly required labels may be used until the dates indicated below at which time the above labels become mandatory.

Explosive labels - Jan. 1, 1974.
All other labels - Jan. 1, 1975.

(continued)

Figure 16. Hazardous materials warning labels.


EXPLOSIVES
CLASS A
EXPLOSIVE A
CLASS B
EXPLOSIVE B
CLASS C
EXPLOSIVE C
UN CLASS 1
COMPRESSED GASES
FLAMMABLE GAS
NON-FLAMMABLE GAS
UN CLA
FLAMMABLE LIQUID
FLAMMABLE LIQUID
UN CLASS 3
FLAMMABLE SOLID
FLAMMABLE SOLID
UN CLASS 4
OXIDIZING MATERIAL
OXIDIZER
ORGANIC PEROXIDE
UN CLASS 5
POISONOUS MATERIAL
CLASS A
POISON GAS
CLASS B
POISON
UN CLASS * 2 OR 6
IRRITATING MATERIAL
DOMESTIC
IRRITANT
IMPORT AND EXPORT
IRRITANT
UN CLASS 6
ETIOLOGIC AGENT
BIOMEDICAL MATERIAL

Required for domestic shipments including the domestic portion of import and export movements.

Note: A Poison Label may be used on import/export shipments in addition to this label.

Figure 16 (continued).

Table 12. HAZARDOUS CHEMICALS DESIGNATED BY THE COAST GUARD

- Acetaldehyde
- Acetone cyanohydrin
- Acetonitrile
- Acrylonitrile
- Allyl alcohol
- Allyl chloride
- Ammonia, anhydrous
- Aniline
- Butadiene
- Carbolic acid
- Carbon disulfide
- Chlorine
- Chlorohydrins, crude
- Crotonaldehyde
- 1,2 dichloropropane
- Dichloropropane
- Epichlorohydrin
- Ethylene
- Ethyl ether
- Ethylene oxide
- Hydrochloric acid
- Methane
- Methyl acrylate
- Methyl bromide
- Methyl chloride
- Methyl methacrylate (Monomer)
- Nonyl phenol
- Oleum
- Phenol
- Phosphorus, elemental
- Propane
- Propylene
- Propylene oxide
- Sulfuric acid
- Sulfuric acid, spent
- Tetraethyl lead
- Tetraethyl lead mixtures
- Vinyl acetate
- Vinyl chloride
- Vinylidene chloride

useful in confirmation of the identity of the spill. The specific properties required are outlined in Section 3.2.3.4. Once these properties are recorded, then OHMTADS (10) can be contacted to run a computer search for chemical identity. This source can be easily referenced and the information obtained as soon as possible. Another way to utilize the information is through the EPA publication "Field Detection and Assessment Manual for Oil and Hazardous Material Spills" (5) The physical properties of many chemicals are listed in this manual and eliminations can be done to establish the identity or eliminate non-spilled chemicals.

3.3.2.7 Step 6 - Identification Through Sampling and Analysis -

The final type of identification is done by sampling the spill in the contaminated area and then analyzing to determine the specific chemical involved. The simplest approach is to indicate to the laboratory performing the analysis what the possible contaminants are. This information can be established from shipping papers, warning labels or physical property identification.

The OSC must contact a qualified analytical laboratory and then relay their specifications to the MOS for sampling. It is important that the sample be delivered to the laboratory as soon as possible to hasten identification of the chemical. Therefore, a laboratory in close proximity to the spill is desirable.

3.3.3 Assessment

3.3.3.1 General - Once the identity of the chemical spilled is known, the assessment of spill magnitude and human danger potential must be established. This process requires utilization of the input from the MOS into prepared programs to assess the danger involved. The OSC will need to contact the CHRIS system and access the HACS computer. This procedure, however, does require both knowledge of the CHRIS system and gathering of necessary input data.

3.3.3.2 Assessment of Human Danger - The most comprehensive resource available is the CHRIS Hazard Assessment Handbook, CG-446-3, the third volume in the four volume set of CHRIS manuals. This handbook and HACS, the associated computer program, can provide extensive information for many types of spill situations. Some of the computer outputs are listed in Table 13. Determination of the appropriate program to use is directly related to the identity of the chemical spill. The second CHRIS manual lists a hazard assessment code for which various calculation procedures can be followed to determine the extent of the hazard involved. This procedure is shown schematically in the Hazard Assessment tree shown in Figure 17.

The geometric shape of the outlined information indicates the type of input required. The oval shapes are indicative of physical properties of the chemical, the triangles indicate the environmental conditions at the spill site, and the rectangles represent the information calculated by the program. Various inputs are required in order to establish the hazard potential. For example, CHRIS requires inputs of primary and secondary information to directly assess the effect of the hazard (See Figure 18). This information is gathered by the MOS and must be transformed into an acceptable form for the HACS or CHRIS input.

3.3.3.3 Magnitude of the Spill - Prior to the use of CHRIS or any other reference, the size of the spill must be determined. There are various ways to establish this information including:

a. Approximate size and description of packages damaged.

b. Determine number of damaged packages.

c. Estimate amount of material released.
(eg. 1/2, 1/4, etc.)

d. Confirm package size and volume estimates from Table 14 and 15 and the data found in the DOT regulations on hazardous materials which regulates amount of material per package. (3)

TABLE 13. CALCULATIONS AVAILABLE IN CHRIS HAZARD ASSESSMENT

Gases (Toxic or Flammable)

- Flame Length
- Flame Angle
- Safe Distances
  - a. For People
  - b. For people with protective clothing
  - c. For wooden buildings
- Travel Time of Gas Cloud
- Duration of Hazard

Liquids

- Flammable
  - Pool size
  - Flame length
  - Safe distances
    - For people
    - For people with protective clothing
    - For wooden buildings

Water Pollution
- Human toxic levels
- Concentration of water at downstream location
- Time of arrival at downstream location
- Maximum distance hazardous to humans

Volatility Hazard
- Maximum downwind extent of flammability hazard
- Maximum half-width of flammability hazard
- Maximum downwind extent of toxic hazard
- Maximum half-width of toxic hazard
- Maximum duration of flammability hazard
- Maximum duration of toxic hazard

Solids
- Reactive Solids
  - Amount of projected reaction products
  - Specific hazard as related to product type

Soluble (same calculations as liquid)

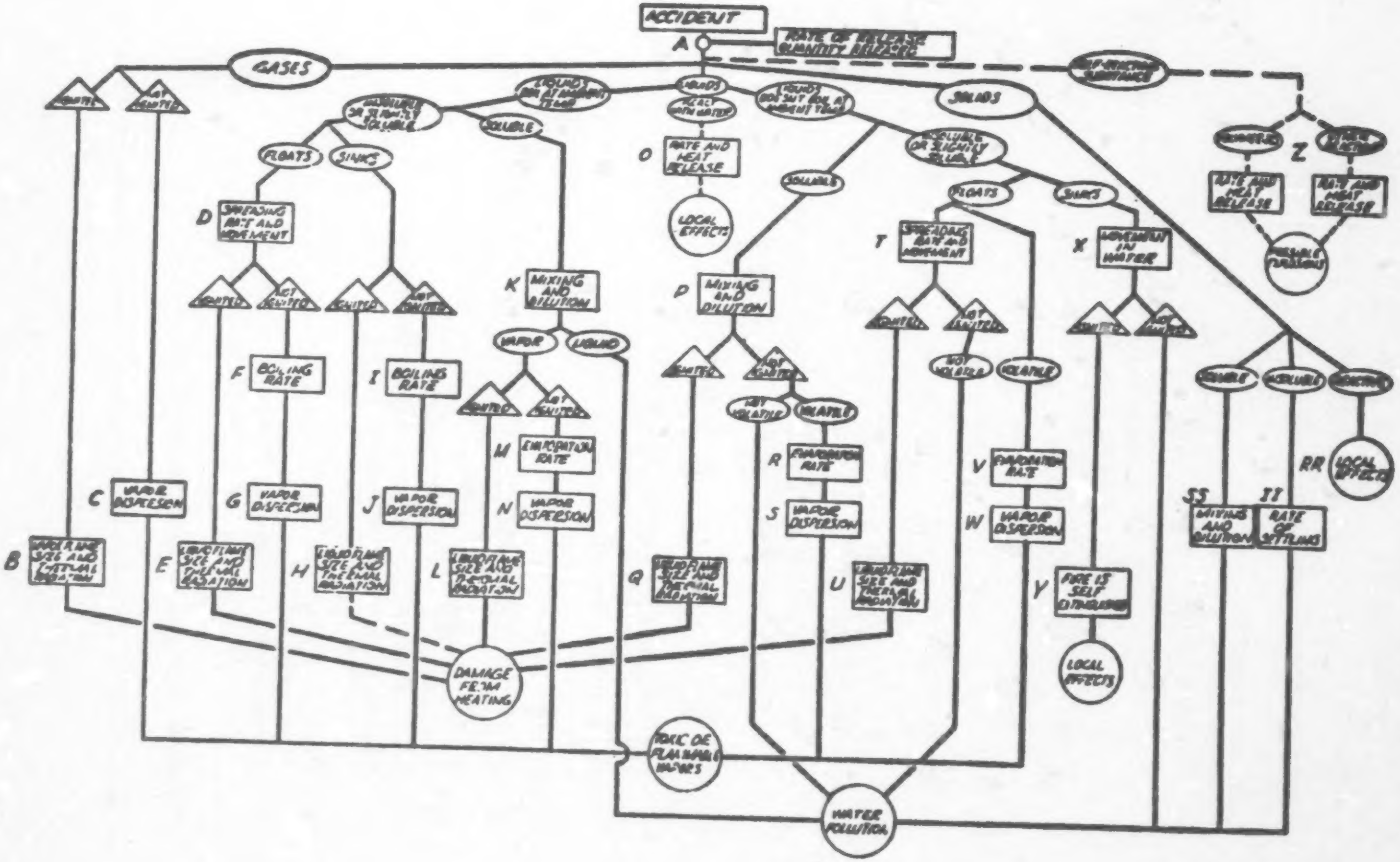

ACCIDENT
A
RATE OF RELEASE
QUANTITY RELEASED
GASES
IGNITED
NOT IGNITED
LIQUIDS BOIL AT AMBIENT TEMP.
INSOLUBLE OR SLIGHTLY SOLUBLE
SOLUBLE
FLOATS
SINKS
D
SPREADING RATE AND MOVEMENT
F
BOILING RATE
I
BOILING RATE
K
MIXING AND DILUTION
VAPOR
LIQUID
M
EVAPORATION RATE
N
VAPOR DISPERSION
C
VAPOR DISPERSION
G
VAPOR DISPERSION
J
VAPOR DISPERSION
B
VAPOR FLAME SIZE AND THERMAL RADIATION
E
LIQUID FLAME SIZE AND THERMAL RADIATION
H
LIQUID FLAME SIZE AND THERMAL RADIATION
L
LIQUID FLAME SIZE AND THERMAL RADIATION
DAMAGE FROM HEATING
SOLIDS
REACT WITH WATER
O
RATE AND HEAT RELEASE
LOCAL EFFECTS
LIQUIDS DON'T BOIL AT AMBIENT TEMP.
SOLUBLE
P
MIXING AND DILUTION
NOT VOLATILE
VOLATILE
R
EVAPORATION RATE
S
VAPOR DISPERSION
Q
LIQUID FLAME SIZE AND THERMAL RADIATION
TOXIC OR FLAMMABLE VAPORS
SOLUBLE OR SLIGHTLY SOLUBLE
FLOATS
SINKS
T
SPREADING RATE AND MOVEMENT
U
LIQUID FLAME SIZE AND THERMAL RADIATION
V
EVAPORATION RATE
W
VAPOR DISPERSION
X
MOVEMENT IN WATER
Y
FIRE IS SELF EXTINGUISHING
LOCAL EFFECTS
WATER POLLUTION
SOLIDS
SOLUBLE
INSOLUBLE
REACTIVE
RR
LOCAL EFFECTS
SS
MIXING AND DILUTION
TT
RATE OF SETTLING
SELF-REACTING SUBSTANCE
Z
RATE AND HEAT RELEASE
RATE AND HEAT RELEASE
POSSIBLE EXPLOSIONS

Figure 17. Hazard Assessment Computer System (HACS) Hazard Assessment Tree (6).

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PRIMARY INFORMATION

1. NAME of chemical ____________
2. TIME discharge began ____________
3. WHERE discharge occurred ____________
4. HOW MUCH was originally present ____________
5. WIND speed and direction ____________
6. CLOUD cover ____________
7. CURRENT speed and direction ____________
8. WIDTH and DEPTH of waterway ____________
9. HOLE DIAMETER (if gas) ____________

SECONDARY INFORMATION

1. a) RATE OF RELEASE if still leaking ____________
    b) TIME TO EMPTY TANK if discharge stopped ____________
    c) AMOUNT LEFT in tank ____________
    d) SIZE, SHAPE of HOLD ____________
    e) LENGTH, WIDTH, SHAPE of TANK ____________
    f) HEIGHT OF LIQUID ABOVE HOLE/WATER ____________
2. WATER TEMPERATURE ____________
3. DEPTH of water near discharge ____________
4. WIDTH if river or channel ____________
5. POOL SIZE if visible ____________
6. ACTION ON RELEASE ____________
7. a) VAPOR CLOUD VISIBLE? ____________
    b) If yes, RISING OR LYING LOW ____________
8. CONDITION OF VESSEL ____________
9. TYPE, SIZE OF VESSEL ____________

Figure 18. Information needs for CG-446-3 summary (6).

TABLE 14. USABLE VOLUME OF SHIPPING CONTAINERS (11)

Container size & description	Usable volume, cu m	cu ft
METAL DRUMS		
55 gal. steel std., 18 gage plate, DOT-17E, new	0.205	7.35
55 gal. steel std., 16 gage plate, DOT-17C, new	0.205	7.35
55 gal. steel, removable head, 18 gage, Rule 40, new	0.205	7.35
55 gal. steel, removable head, 18/16 gage, DOT-17H, new	0.205	7.35
55 gal. steel, removable head, 18 gage, used, reconditioned	0.205	7.35
55 gal. steel, std., 18 gage, used, inspected, cleaned	0.205	7.35
55 gal. aluminum, std., 0.102 in. plate	0.205	7.35
55 gal., type 304 stainless steel, std., 16 gage, DOT-5C	0.205	7.35
30 gal., steel, std., 20 gage, DOT-17E	0.112	4.00
30 gal., steel, removable head, 20-gage, Rule 40	0.112	4.00
16 gal., steel, removable lug cover, 22 gage	0.059	2.14
55 gal., steel-mill galvanized, std., 18 gage, DOT-17E	0.205	7.35
55 gal., steel, removable head, 40-mil polyethylene liner, external fittings, 20/18 gage, 53.5 gal. usable volume, DOT-37M	0.201	7.20
FIBER DRUMS		
61 gal., 9 ply, 400 lb load limit, dry products only, Rule 40	0.228	8.15
55 gal., 9 ply, 400 lb load limit, dry products only, Rule 40	0.205	7.35
47 gal., 9 ply, 400 lb load limit, dry products only, Rule 40	0.175	6.28
41 gal., 9 ply, 400 lb load limit, dry products only, Rule 40	0.153	5.48
30 gal. 9 ply, 400 lb load limit, dry products only, Rule 40	0.112	4.00
30 gal. 7 ply, 225 lb load limit, dry products only, Rule 40	0.112	4.00
15 gal. 6 ply, 150 lb load limit, dry products only, Rule 40	0.056	2.00
55 gal. 9 ply, polyethylene barrier, 400 lb load limit, Rule 40	0 .205	7.35
55 gal. 9 ply, polyethylene-aluminum foil liner, 400 lb load limit, Rule 40	0.205	7.35
55 gal. 10 ply blow-molded 15 mil polyethylene liquid-tight liner, tight head, steel cover with 2 3/4" NPT openings, 600 lb load limit, DOT-21C.21CP liquid products	0.205	7.35
30 gal. 9 ply, same as preceding except 450 lb load limit	0.112	4.00
30 gal. 8 ply, 300 lb load limit, removable fiber cover no barrier	0.112	4.00
15 gal. 6 ply, same as preceding except 150 lb load limit	0.056	2.00
1 gal. 5 ply, same as preceding except 150 lb load limit	0.003	0.1335
55 gal. 9 ply, 400 lb load limit, semisquare removable fiber cover, "Rocon" style	0.205	7.35
45 gal., same as preceding	0.168	6.01

continued

TABLE 14 (continued)

	Usable volume,	
	cu m	cu ft
BAGS, MULTIWALL PAPER, POLYETHYLENE (PE) FILM		
Pasted-valve bag, 20 1/2 x 22-in. face, 5 1/2-in. top and bottom with 1-mil free film, 2/50, 1/60 kraft, plain, no printing, PE internal sleeve	0.037	(1.33)
Sewn-valve bag, 15 x 5 1/2 x 30 1/4 in. 5 1/2-in. PE internal sleeve with 1-mil free film, 2/50, 1/60 kraft, plain, no printing	0.0037	(1.33)
Pasted-valve bag, 18 1/2 x 22 3/4 in., 3 1/2-in. top and botton, PE internal sleeve, 3/50 kraft, plain, no printing	0.023	(0.84)
Sewn open-mouth bag, 20 x 4 x 30 3/4 in., 3/50, 1/60 kraft, plain	0.056	(2.00)
Sewn-valve bag, 19 x 5 x 33 1/2 in., 5 1/2-in. tuck-in sleeve, 3/50, 1/60 kraft, plain	0.056	(2.00)
Pasted-valve bag, 24 x 25 1/4 in., 5 1/2-in. top and bottom, tuck-in sleeve, 3/50, 1/60 kraft, plain	0.056	(2.00)
Pasted open-mouth baler bags, 22 x 24 in., 6-in. bottom, 1/130 kraft (or 2/70), plain	--	
Flat-tube, open-mouth bag, 10-mil PE film, plain, 20 1/2 x 34 1/4 in.	0.037	(1.33)
Square - end valve bag, 20 1/2 x 22-in. face, 5 1/2-in. top and bottom, 10-mil PE film, plain	0.037	(1.33)
SMALL BAGS, POUCHES, FOLDING BOXES		
Pouch, 8 3/4 x 16 3/4 in., 2-ply PE film. 2-ml thickness/ply	0.003	(0.12)
Bag, sugar-pocket style, 6 x 2 3/4 x 16 3/4 in., 2- to 40-lb. basis weight, natural kraft paper	0.003	(0.12)
Bag, pinch style, 8 3/4 x 3 x 21 in., 2- to 40-lb. basis weight, natural kraft	0.003	(0.12)
Folding box, 5 x 1 x 8 in., reverse-tuck design, 12-point kraft board with bleached white exterior	0.0008	(0.028)
Folding box, 9 1/2 x 4 1/2 x 15 in., full overlap top and bottom, 30-point chip board with bleached white exterior	0.01	(0.37)
CORRUGATED CARTONS, BULK BOXES		
Regular slotted carton (RSC), 24 x 16 x 6 in., 275-lb. test double wall, stapled (stiched) joint	--	
RSC, 16 x 6 x 24 in., 275-lb. test double wall, stitched joint, end-opening style	--	

continued

TABLE 14 (continued)

Bag-in-box, RSC, 15 x 15 x 22 in. 275-lb. test double wall, stitched liner, 600-lb. test	0.08 (2.86)
Bulk box 200/600 (test in lb. for both pieces), laminated inner lining approximately 41 x 34x 36 in., less PE liner and pallet	0.14 (5.00)
CARBOYS, PLASTIC DRUMS, JARS, BOTTLES	
Carboy, 13 1/2 gal., polyethylene, blow-molded	0.037 (1.35)
Drum, polyethylene, 15 gal., blow-molded, ICC-34 (DOT-34)	0.056 (2.00)
Carboy, 15 gal., glass, nitric acid service, wooden crate	0.056 (2.00)
Jug, 1 gal., glass, with finger handle, plastic cap	0.003 (0.1335)
Bottle, 1 qt. glass, "Boston" round, plastic cap	0.0009 (0.034)
Jar, 1 qt., glass, wide mouth, plastic cap	0.0009 (0.034)
Jar, 1 gal., polyethylene, wide mouth, plastic cap	0.0037 (0.1335)
Bottle, 1 gal. polyethylene, narrow neck, plastic cap	0.0037 (0.1335)
Bottle, 1 qt. polyethylene, wide mouth, plastic cap	0.0009 (0.034)
Jar, 1 pt. polyethylene, wide mouth, plastic cap	0.0004 (0.017)
CANS, PAILS	
Pail, 5 gal., steel, tight head, 26-gage black steel, PE pour spout, unlined	0.0187 (0.67)
Pail, 5 gal., 26-gage black steel, removable head, unlined, lug cover, wire bail handle	0.0187 (0.67)
Can, 1 gal., friction wedge lid, handle (paint can)	0.0037 (0.1335)
Can, 1 qt. friction wedge led (paint can)	0.0037 (0.034)
Can 1 gal. oblong "F" style, handle, screw cap	0.0037 (0.1335)
Can 1 qt. oblong "F" style, screw cap	0.0037 (0.034)

TABLE 15. TYPICAL CARRIER CAPACITIES

Tank Truck	(11)	Average 70,000 lb. Total Wt. 30,000 lb/for tandem axles 60 ft. in length Labeled according to capacity	
Tank Car	(11)	Labeled according to capacity	
Ship Tankers		Size not limited (estimate cubic size)	
Barges	(12)	a. 35 ft. wide x 195 ft. long x 9' draft	
		b. 52.5 ft. wide x 520 ft. long x 14' draft	
No. Containers per car load truck or train	(11)	Fiber Drums	Number/Carload
		61 gal. size	300
		55 gal. size	318
		47 gal. size	424
		41 gal. size	552
		30 gal. size	592
		15 gal. size	1,272
		1 gal. size	17,365
		Metal Drums	
		55 gal. size	360
		30 gal. size	592
		16 gal. size	1,225

lbs x 0.454 = kg gal x 3.785 = l

ft x 0.305 = m

8. Width and Depth of Waterway or Size of Land Area Affected - The MOS can transfer this information or the OSC can determine this from maps available from USGS.

9. Hole Diameter (if gas) - The MOS must estimate this information from a distance and relay it to the OSC.

SECONDARY INFORMATION (FOR HACS USAGE)

1. a. Rate of Release, if still leaking - Various methods are available for estimating the rate of the leak. The MOS can transfer the information to the OSC who can do the necessary calculations. For ship holds, the rate of leakage can be estimated if knowledge of the type of hole, water depth and list of the ship is known (Figures 19-22). If the source can be approached, the rate of leak can be determined by depth differences over a known amount of time. An example follows:

Steps 1-4:

At time 10:30 a.m. a "dipstick" is put down into a 20-foot long by 10-foot wide tank. It is pulled up and it is noted that 96 inches of the pole are "wet". At 10:45 a.m. the procedure is repeated and it is determined that 72 inches of the pole are "wet".

Step 5:

$$96'' - 72'' = 24''$$

$$24'' \times 1\ \text{ft}/12'' = 2\ \text{ft}$$

Step 6:

$$2\ \text{ft} \times 20\ \text{ft} \times 10\ \text{ft} = 400\ \text{cubic ft}$$

$$\frac{400\ \text{cubic ft}}{15\ \text{min}} = 26.66\ \frac{\text{cubic ft}}{\text{min}}$$

Step 7:

$$26.66\ \frac{\text{cubic ft}}{\text{min}} \times \frac{7.48\ \text{gal.}}{\text{cubic ft}} = 199.3\ \frac{\text{gal.}}{\text{min.}} = \text{rate of release}$$

$$\frac{\text{gal.}}{\text{min.}} \times 3.784 = \frac{\text{l}}{\text{min.}}$$

b. Time to Empty Tank (if discharge is stopped) - This information can be obtained by the MOS by eyewitnesses at the scene.

c. Amount left in Tank - The estimate based on the percent of material left in the tank is made by the MOS.

d. Size, Shape of Hold (if applicable) - If a hold is involved, the size can be estimated by the MOS, alternately the ship's registration papers should include this information.

e. Length, width and shape of tank - The MOS should also give this information or the best estimates. If these are not available, the registration papers of the tank car should give the information.

f. Height of Liquid Above Hole/Water - The height is determined by the MOS and relayed to the OSC.

2. Water Temperature - The MOS can establish the temperature by borrowing a thermometer or possibly certain agencies may have this information available.

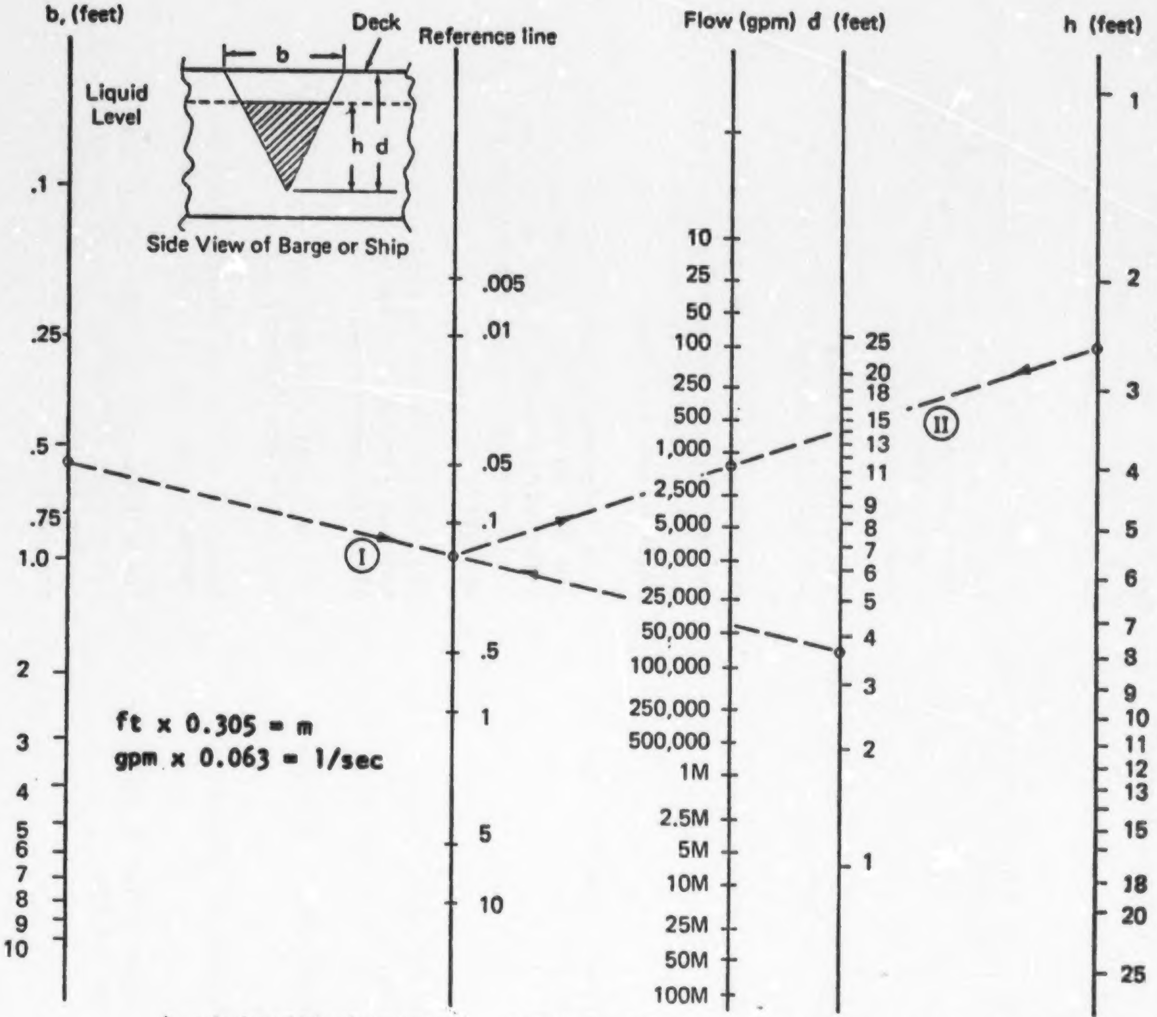
3. Depth of Water Near Discharge - This information can be relayed to the OSC by the MOS. If an on site depth measurement is not possible, a similar upstream location can be measured.

4. Width (if river or channel) - The MOS can estimate this or the OSC can use maps of the water body to get an approximate value.

5. Pool Size, if visible - The MOS must estimate the pool size and relay the information to the OSC.

6. Action on Release - Specific action of the chemical on release must be reported to the OSC.

7. Vapor Cloud Visibility and Action - The existence of a vapor cloud and its action regarding low lying or rising is needed to be reported by the MOS.



Instructions for use are on page 29.

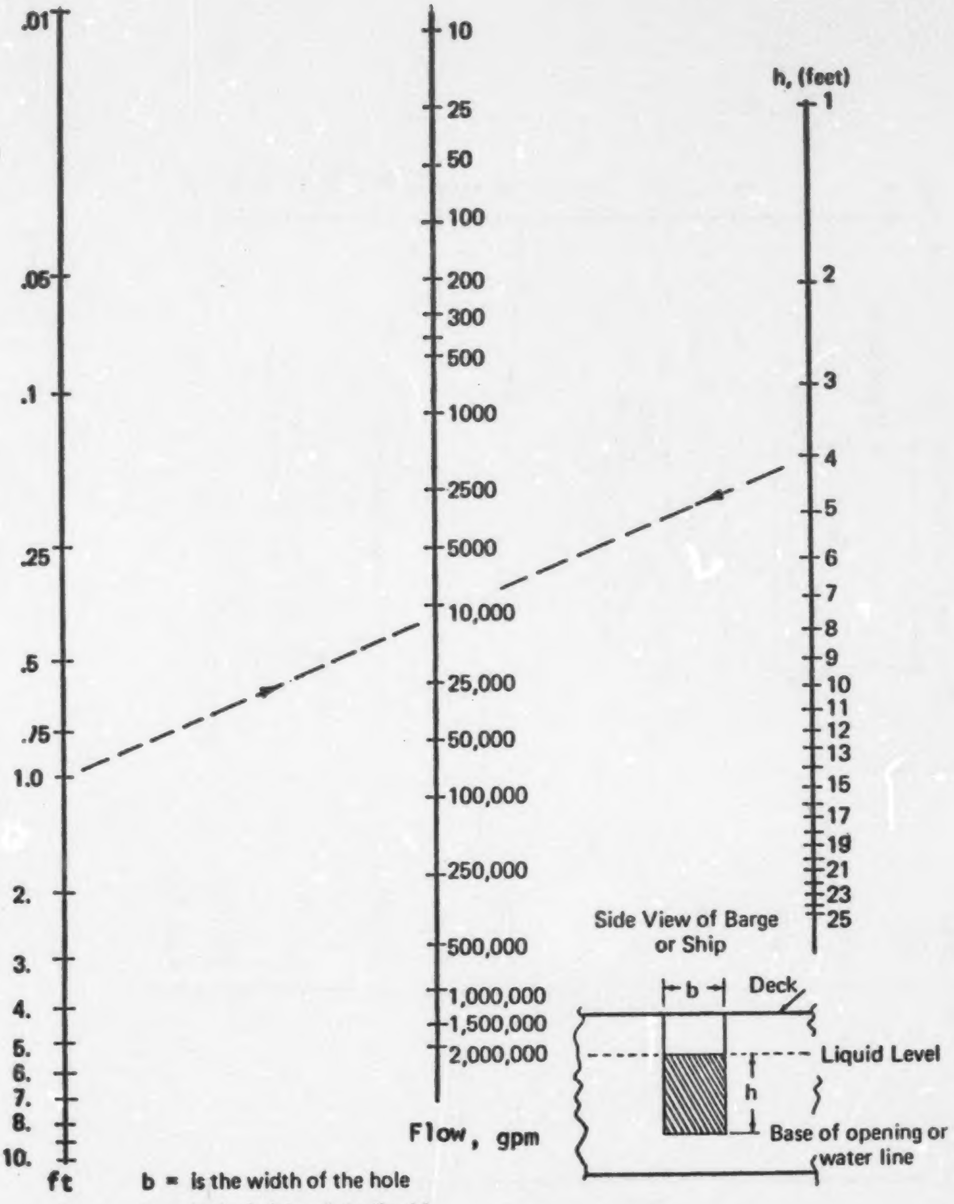
ft x 0.305 = m
gpm x 0.063 = l/sec

b = is the width of the hole

d = is the distance from the deck to the bottom of the hole

h = is the height of the liquid level above the bottom of the hole

Figure 19. Rate of chemical discharge from triangular notch-shaped openings.(6)



b = is the width of the hole

h = is the height of the liquid level above the bottom of the hole or the water level, whichever is higher.

ft x 0.305 = m
gpm x 0.063 = l/sec

Figure 20. Rate of chemical discharge from a rectangular slot-shaped opening. (6)

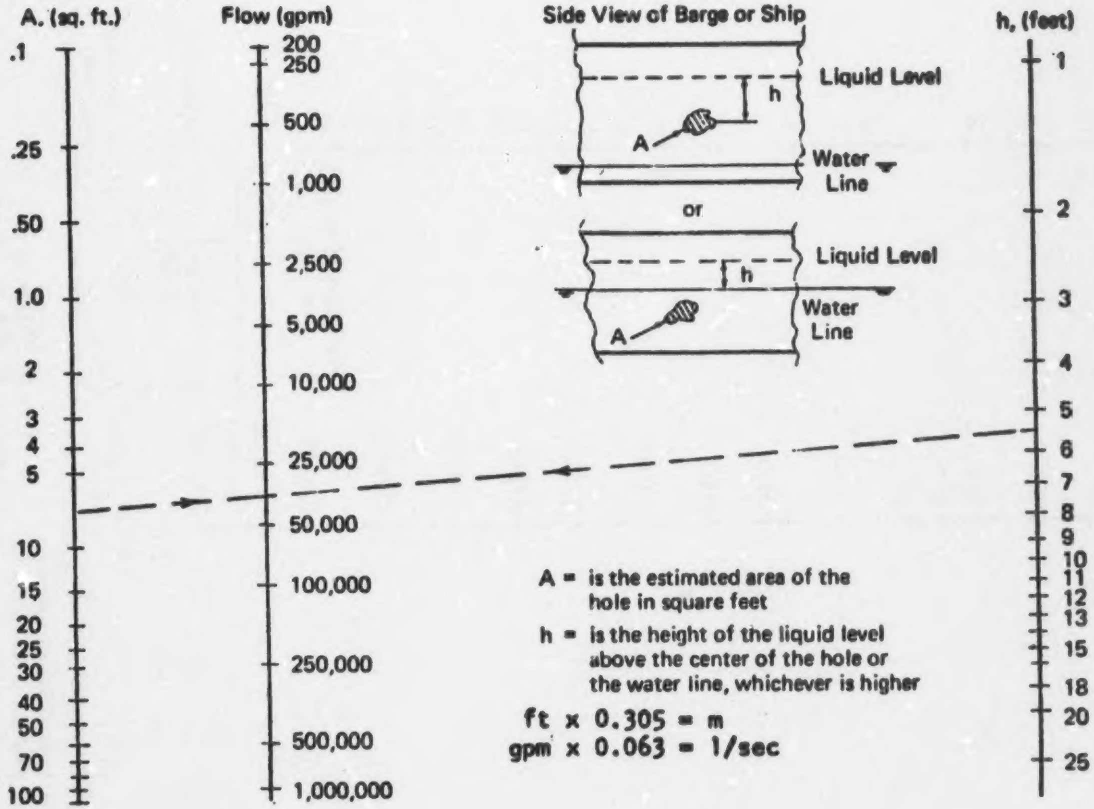


Figure 21. Chemical discharge from irregularly shaped holes. (6)

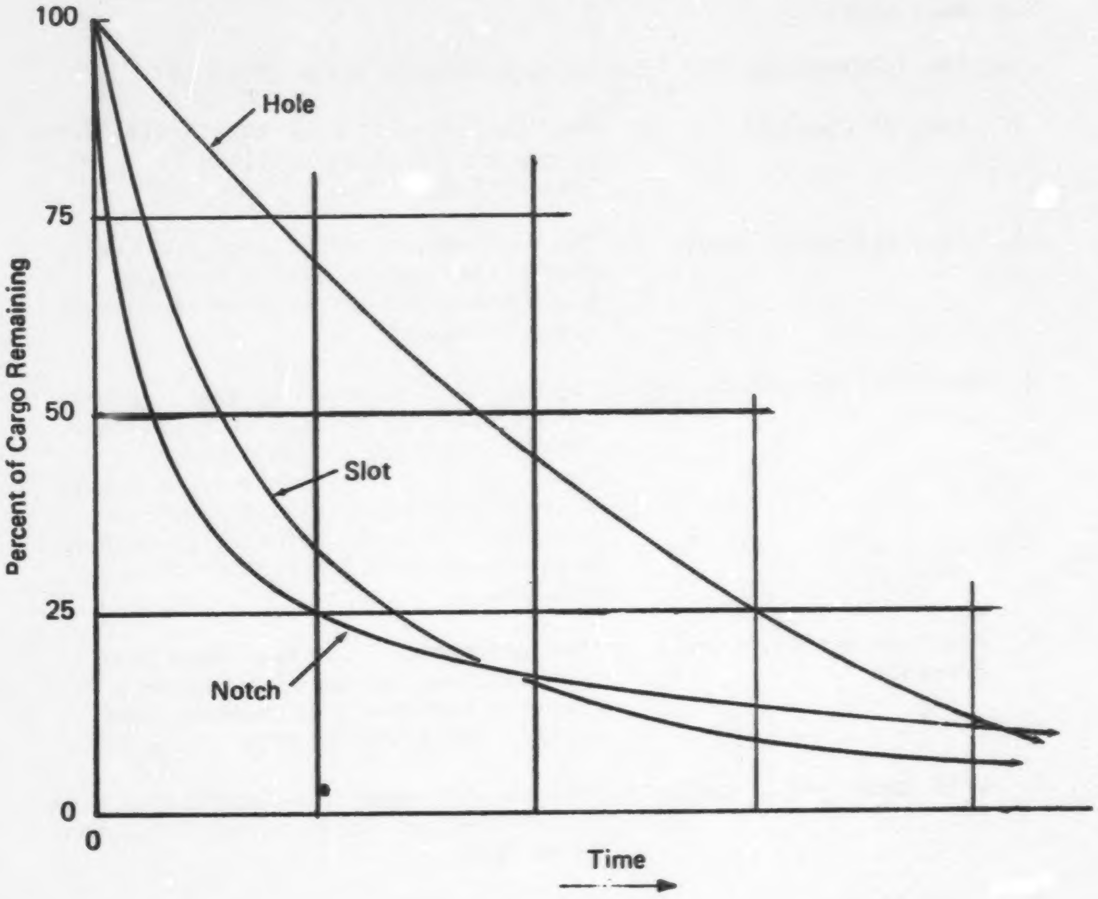


Figure 22. Comparative cargo loss versus time for three types of opening (6)

3.3.3.4 Establishing Inputs for Assessment Calculations - Required inputs for the CHRIS manual CG 446-3 and the HACS computer program are shown in Figure 18. The MOS will have answered various questions regarding the spill problems and must relay this information to the OSC (Section 3.2.4.3) The OSC can copy the answers, direct the MOS to further action and then begin compilation of data to input CHRIS.

PRIMARY INFORMATION (for hand calculations in CHRIS CG446-3)

1. Name of Chemical - The identity will have to be established by one of the steps outlined in Section 3.3.2
2. Time Discharge began - The information on the specific discharge time can be determined from the MOS who has interviewed various on scene witnesses.
3. Where Discharge Occurred - The specific location of the discharge is indicated by the MOS in Question 2. This information is augmented by Questions 3 and 4 regarding the proximity to populated areas and drinking supplies. The OSC should also consult maps of the area to pinpoint other hazards.
4. How Much Was Originally Present? - The information is established from the size, and number of containers involved and then confirmed by consulting DOT shipping regulations (3)
5. Wind Speed and Direction - The MOS will relay the information from either Beaufort Chart or Weather Bureau summaries.
6. Cloud Cover - Again, the MOS can relay the percent of the sky covered with clouds.
7. Current Speed and Direction (when applicable) - The current speed is found using the following formula.

$$\text{Current Speed} \left(\frac{\text{ft.}}{\text{sec.}}\right) = 0.8 \times \frac{\text{distance measured (straight) ft.}}{\text{time to cover distance (sec)}}$$

The direction is given by the MOS or found on maps. (ft/sec x 0.305 = m/sec)

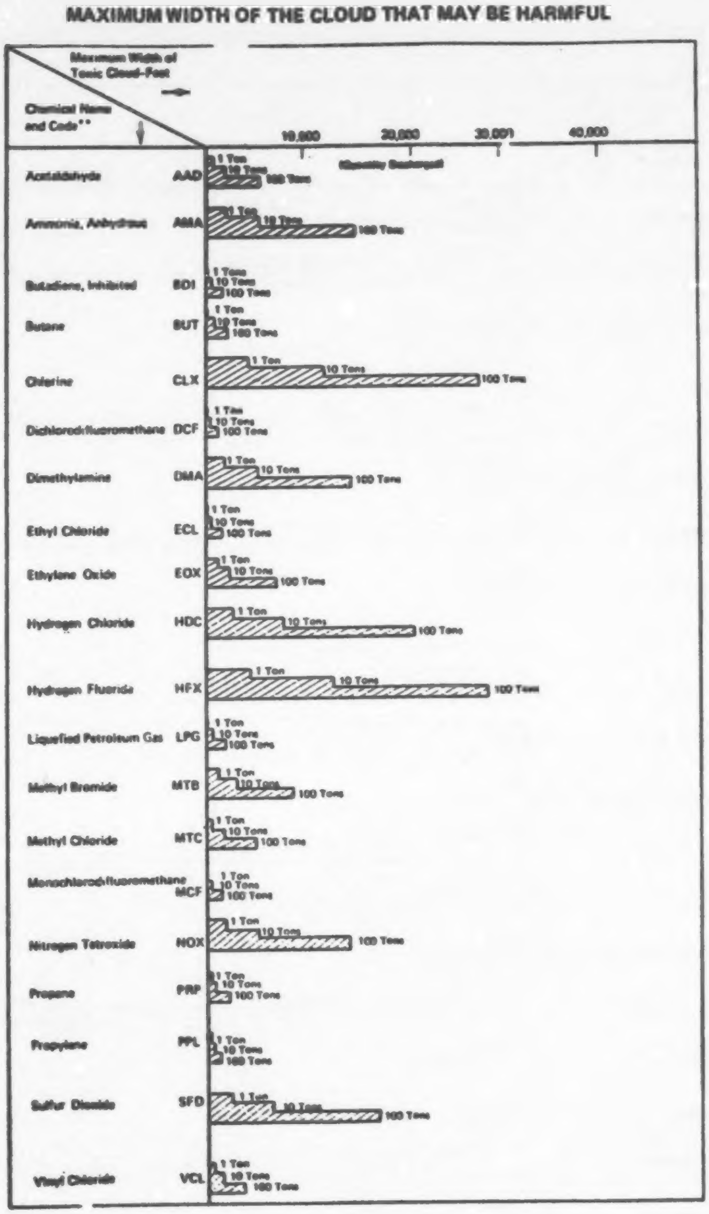
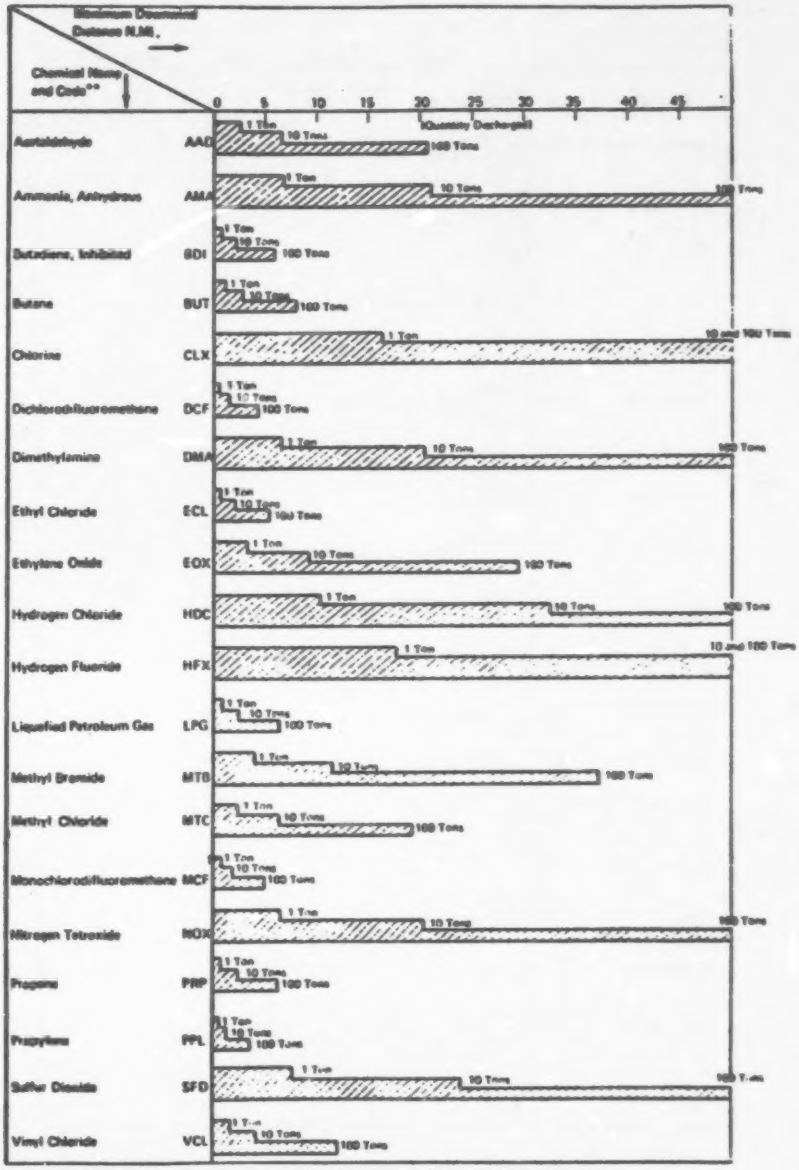


Figure 23. Effects of Toxic Gases (6).

MAXIMUM DOWNWIND DISTANCE OVER WHICH GASES MAY BE HARMFUL*†



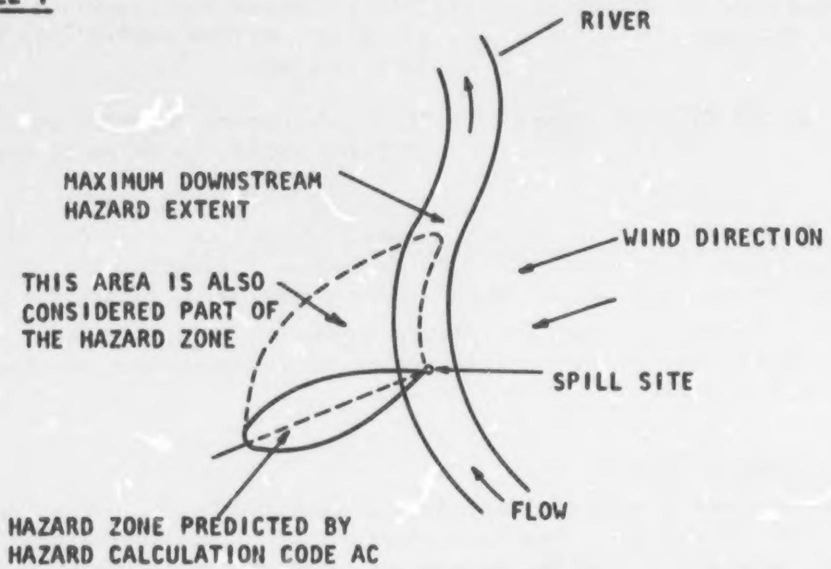
*Hazard calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge

†See Table 5.3 for time of arrival and duration of cloud.

**See Condensed Guide to Chemical Hazards (CG-446-1).

Figure 23. (continued)

EXAMPLE 1


RIVER
MAXIMUM DOWNSTREAM HAZARD EXTENT
WIND DIRECTION
THIS AREA IS ALSO CONSIDERED PART OF THE HAZARD ZONE
SPILL SITE
FLOW
HAZARD ZONE PREDICTED BY HAZARD CALCULATION CODE AC

EXAMPLE 2

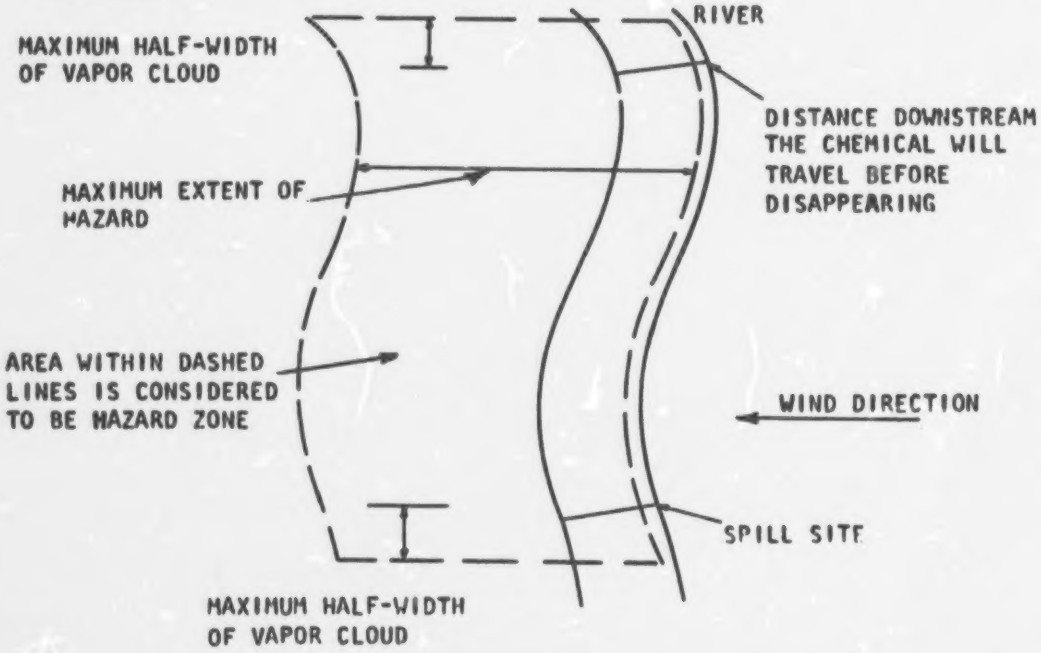

RIVER
MAXIMUM HALF-WIDTH OF VAPOR CLOUD
DISTANCE DOWNSTREAM THE CHEMICAL WILL TRAVEL BEFORE DISAPPEARING
MAXIMUM EXTENT OF HAZARD
AREA WITHIN DASHED LINES IS CONSIDERED TO BE HAZARD ZONE
WIND DIRECTION
SPILL SITE
MAXIMUM HALF-WIDTH OF VAPOR CLOUD

Figure 24. Wind effect on hazard zone (6).

8. Condition of Vessel or Vehicle - This indicates the stability of the situation and the possibility for leak stoppage.

9. Type and Size of Vessel - This information reported by the OSC pertains mainly to ships at sea.

3.3.3.5 Application of the Assessment Information - The OSC will then receive output from the HACS computer system indicating the affect of the hazards on downwind or downstream populations. (See Figures 23-24)

This information can then be relayed to the Civil Defense Agency or police department so appropriate action to safeguard the population can then be taken.

3.3.4 Remedial Action

Various methods of remedial action are appropriate, once the identity and danger of the spill has been assessed. The remedial action may involve covering the spill, absorption, chemical addition to change the pH or other actions. The comments section of the chemical treatment scheme in Chapter 4 indicates some remedial action. CHEMTREC and other emergency agencies should be consulted regarding other possible steps to take.

4.0-CHAPTER 4 - DETERMINATION OF THE BEST METHOD FOR SPILL HANDLING

4.1 GENERAL

Once the spill has been identified and assessed, the best containment and handling method must be determined. This chapter presents methods to allow the user to determine the best techniques for a specific situation. The chapter covers containment, choosing the best handling method, and specifics regarding handling techniques including over 300 schemes for treatment of different hazardous chemicals. The chapter is used in conjunction with Chapters 5-7 to complete the construction of a treatment system if treatment has been selected as the best handling method. The methods of following Chapter 4 and its integration with other chapters is shown in Figure 25.

4.2 CONTAINMENT OF SPILLED MATERIALS

4.2.1 Stepwise Approach to Containment

The following steps should be taken when containment of a spill is necessary: (a discussion follows)

1. Establish identity. (Chapter 3)
2. Establish human safety hazard and take appropriate safety precautions and/or remedial action. (Chapter 3)
3. Stop discharge whenever possible.
4. Note location of spill

    on land
    on water
    in water
    under water
    in air

5. Refer to appropriate figure (or figures for combined spills), the accompanying text, and the appropriate oil spill containment references, if necessary.
6. Choose a method of containment which seems best.
7. Evaluate choice by answering the corresponding questions.
8. If all answers lead to containment, proceed taking adequate safety precautions.
9. If containment by that method is not feasible, choose another possible technique and evaluate it.

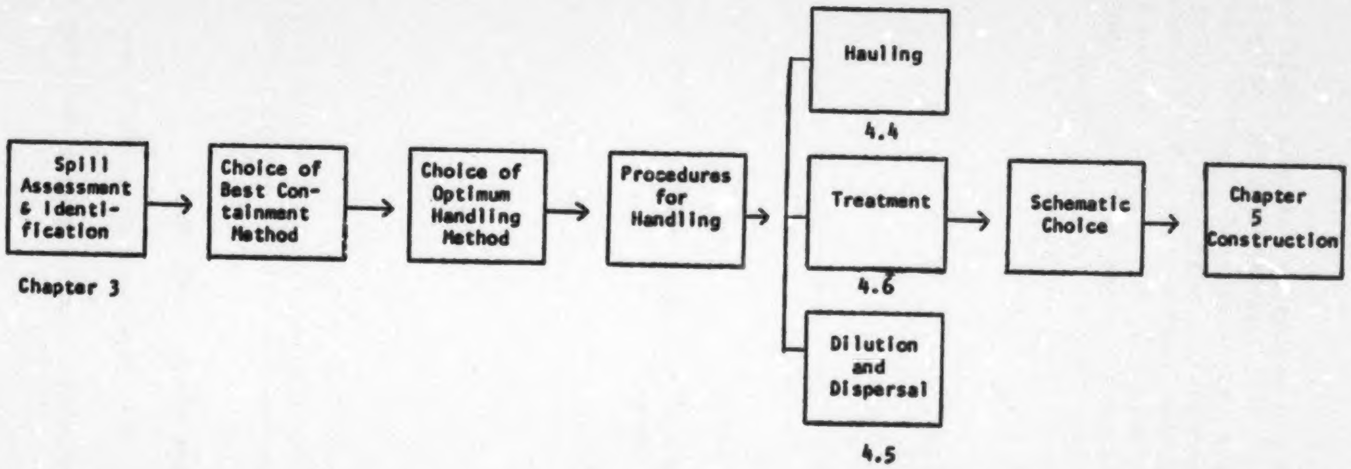

Spill Assessment & Identification
Chapter 3
Choice of Best Containment Method
Choice of Optimum Handling Method
Procedures for Handling
Hauling
4.4
Treatment
4.6
Dilution and Dispersal
4.5
Schematic Choice
Chapter 5 Construction

Figure 25. Use of Chapter 4.

10. Continue to evaluate alternatives until a method is established or no feasible containment method is found.

Steps 1 & 2 Identification and Assessment - Use the procedures outlined in Chapter 3 to identify and assess the spill. Do not contain the spill without knowing the identity and hazard potential because the MOS may be exposed to great danger.

Step 3 Stop Discharge Whenever Possible - To do this the MOS must approach the spill so adequate safety measures must be taken. Procedures to stop the discharge are listed below and are only included as possible suggested methods:

1. Close valves and shut off pumps - especially if a transfer operation is involved.

2. Rebuild or repair container - includes rebuilding, reinforcing, patching and insertion of plugs (13) both to the inside (rags to get caught in the leak) and from the outside (wooden plugs forced into hole to reduce area of leak).

3. Change the position of the container - move the container so the leak is at the highest level.

4. Transfer or collect the material from the leaking container - usually into an undamaged container of the same or similar type.

5. Encase the entire container or construct a suitable alternate - either overpacks or actual containment can be done in this circumstance (14).

The situation must be evaluated and then the MOS must determine if one of these procedures is applicable, or safe.

Steps 4 & 5 Locate Spill and Refer to Figure Summaries - The next step involves establishing the specific location of the spill, i.e., on land, in, on or under water, or in air. The spill could be located in a combination of media and this factor must be noted. Then the MOS must refer to Figures 26-30 which summarize the containment methods for various spills (15). It must be emphasized that the figures present diagrams to illustrate the containment technique. Details regarding its implementation are not included. The MOS must refer to the references listed in Table 16 for the needed background on containment.

Step 6 Choose Apparent "Best" Containment Method - The choice is made from knowledge of the type and size of the area affected by the spill, meterological conditions, and the materials available to the MOS. These materials can either be immediately on hand, which is the best situation, or can be brought to the scene in a short time. Other considerations are the safety hazard and the toxicity of the material spilled, the proximity to populated areas or water sources, and the accessibility to the spill

TABLE 16. OIL CONTAINMENT REFERENCES

Ayers, R.R., *A Rigid Perforated Plate Oil Boom for High Currents*, Report No. EPA 600/2-76-263, National Technical Information Service, Springfield, Virginia 22161, 1976.

Bonz, P.E., *Fabric Boom Concept for Containment of Floating Oils*, Report No. EPA 670/2-73-069, National Technical Information Service, Springfield, Virginia 22161, 1973.

Breslin, M.K., *Testing of Boom Configurations for Calm Water Spill Containment*, EPA Report, Oil and Hazardous Materials Spills Branch, U.S. E.P.A., Edison, New Jersey 08817, 1977.

Guide to Water Cleanup - Materials and Methods, Arthur D. Little/Learning Systems, Cambridge, Massachusetts 02140, 1974.

McCracken, W.E., *Hydrodynamics of Diversionary Booms*, EPA Report, Oil and Hazardous Materials Spills Branch, U.S. E.P.A., Edison, New Jersey 08817, 1977.

McCracken, W.E., *Performance Testing of Selected Inland Oil Spill Control Equipment*, Report No. EPA 600/2-77-150, National Technical Information Service, Springfield, Virginia 22161, 1977.

McCracken, W.E. and Schwartz, S.H., *Performance Testing of Spill Control Devices on Floatable Hazardous Materials*, EPA Report, Oil and Hazardous Materials Spills Branch, U.S. E.P.A., Edison, New Jersey 08817, 1977.

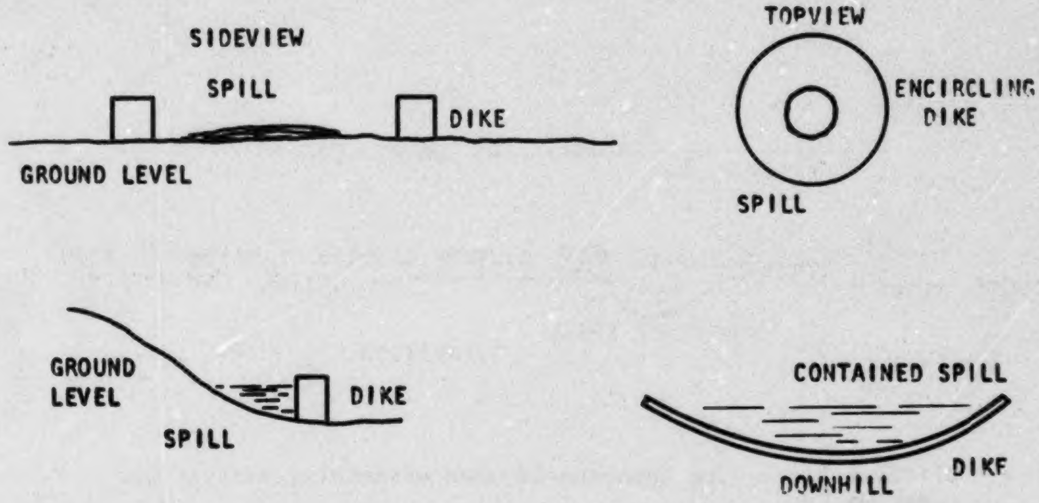
Proceedings, 1973 Oil Spill Conference, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037, 1973.

Proceedings, 1975 Oil Spill Conference, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037, 1975.

Proceedings, 1977 Oil Spill Conference, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037, 1977.

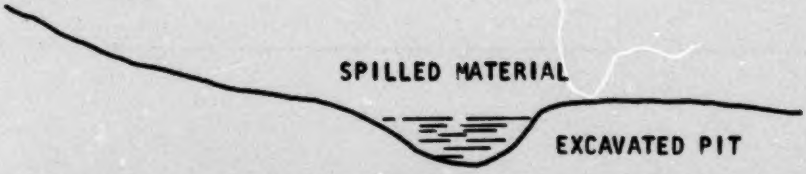
Schwartz, S.H., *Performance Testing of the Navy Standard Boom and P.A.A. Boom*, EPA Report, Oil and Hazardous Materials Spills Branch, U.S. E.P.A., Edison, New Jersey 08817, 1977.

I. DIKING


SIDEVIEW
SPILL
DIKE
GROUND LEVEL
TOPVIEW
ENCIRCLING DIKE
SPILL
GROUND LEVEL
DIKE
SPILL
CONTAINED SPILL
DIKE
DOWNHILL

1. Suitable dike materials must be available, either natural soil, sand bags or foam.
2. Proper earth moving equipment or specialized foam dike equipment must be obtainable.
3. An advantageous site must be available.
4. This procedure may not eliminate percolation of the spill through the soil.

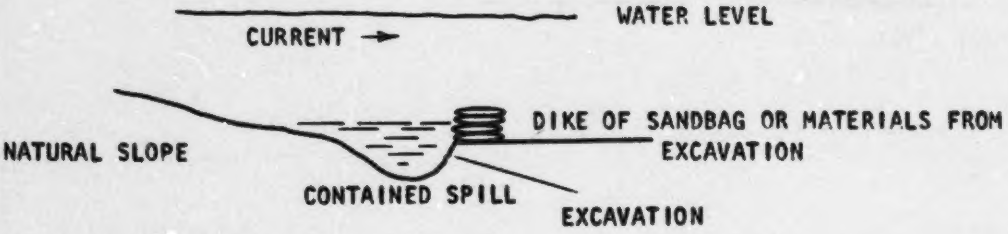
II. EXCAVATIONS


SPILLED MATERIAL
EXCAVATED PIT

1. Equipment and land must be available to accommodate the excavation.
2. In certain areas, soil or subsoil nature may render excavation impossible or ineffective.

Figure 26. Containment of spills on land.

I. EXCAVATION AND DIKING


WATER LEVEL
CURRENT →
DIKE OF SANDBAG OR MATERIALS FROM EXCAVATION
NATURAL SLOPE
CONTAINED SPILL
EXCAVATION

1. Difficulties may be encountered when attempting excavations under water.

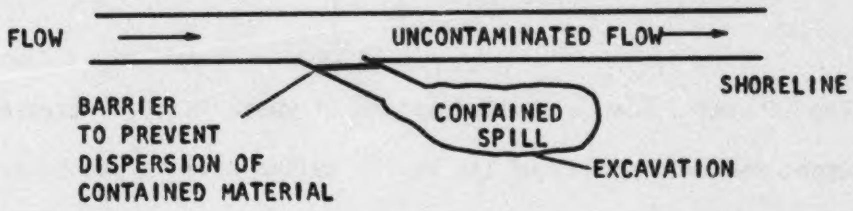
2. Natural forces such as currents or slope of the bottom may be utilized advantageously.

3. Increased turbidity may hamper the activity of scuba divers.

4. Material needs may include divers, pumps, earthmoving equipment, dredges, and diking material.

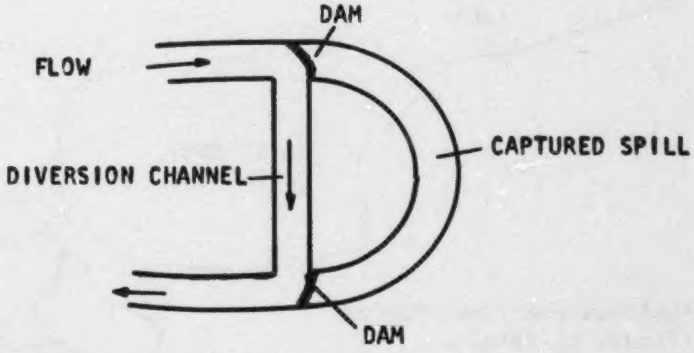
Figure 27. Containment of spills heavier than water.

I. DIVERSIONS



FLOW
UNCONTAMINATED FLOW
SHORELINE
BARRIER TO PREVENT DISPERSION OF CONTAINED MATERIAL
CONTAINED SPILL
EXCAVATION

1. The equipment and suitable land areas must be available for a large excavation upon short notice.
2. An effective method of backfilling the excavation must be available.
3. It is possible to use pumps for stream diversion.



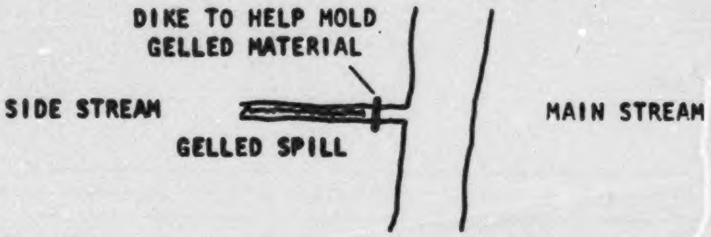
DAM
FLOW
CAPTURED SPILL
DIVERSION CHANNEL
DAM

1. Equipment and suitable land area must be available for a large excavation upon short notice.
2. An effective method of enclosing the spill with dams must be available.

continued

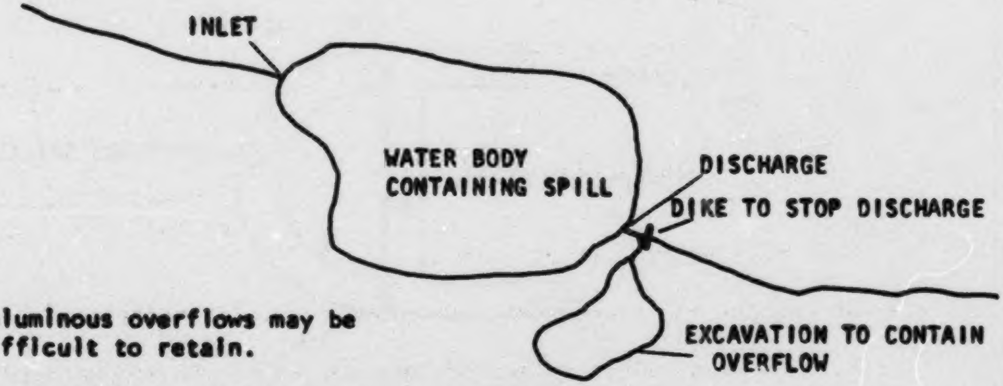
Figure 28. Containment of an entire water mass

II. GELLING


DIKE TO HELP HOLD GELLED MATERIAL
SIDE STREAM
GELLED SPILL
MAIN STREAM

1. Gelling is useful when a limited volume of waste is to be treated.
2. Treatment and/or disposal of the entire gelled mass is necessary.
3. Application of gelling agents must be implemented a short time after the spill occurs.
4. Trained personnel and specialized equipment must be available.

III. CONTAINING AN ENTIRE WATER BODY


INLET
WATER BODY CONTAINING SPILL
DISCHARGE
DIKE TO STOP DISCHARGE
EXCAVATION TO CONTAIN OVERFLOW

1. Voluminous overflows may be difficult to retain.
2. Earthmoving equipment must be obtainable.
3. When more than one overflow originates from a waterbody, all overflows must be contained.

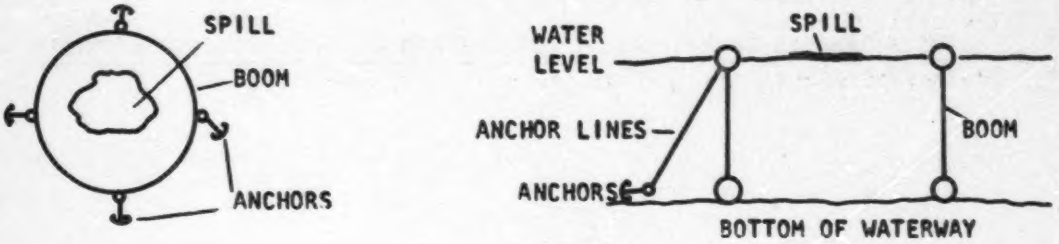
continued

Figure 28 (continued)

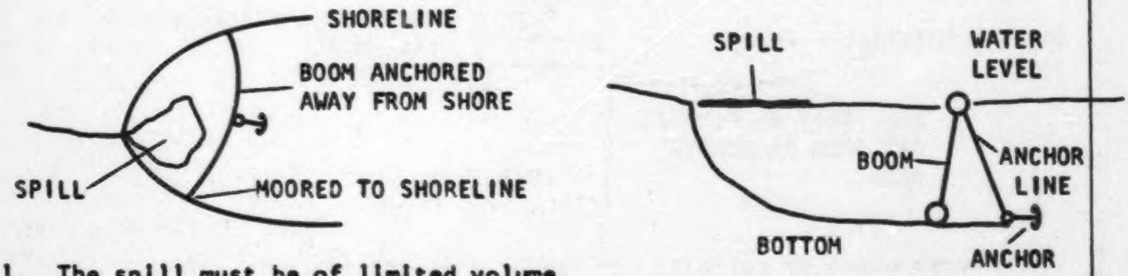
IV. SEALED BOOMS

TOP VIEWS SIDE VIEWS

EXAMPLE 1


SPILL
BOOM
ANCHORS
WATER LEVEL
SPILL
ANCHOR LINES
BOOM
ANCHORS
BOTTOM OF WATERWAY

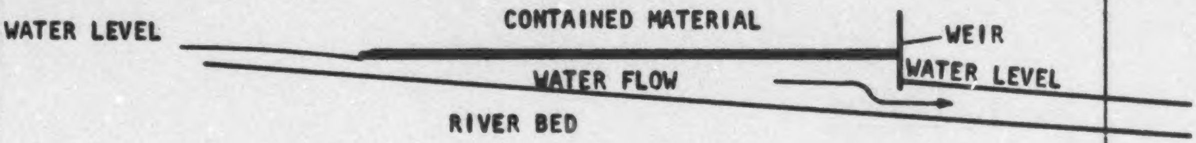
EXAMPLE 2


SHORELINE
BOOM ANCHORED AWAY FROM SHORE
SPILL
MOORED TO SHORELINE
SPILL
WATER LEVEL
BOOM
ANCHOR LINE
BOTTOM
ANCHOR

1. The spill must be of limited volume.
2. Wind or current may render this containment method ineffective.
3. Difficulties in obtaining a sealed boom system may be encountered.
4. This containment method is applicable in shallow water only due to bottom seal and anchoring difficulties.

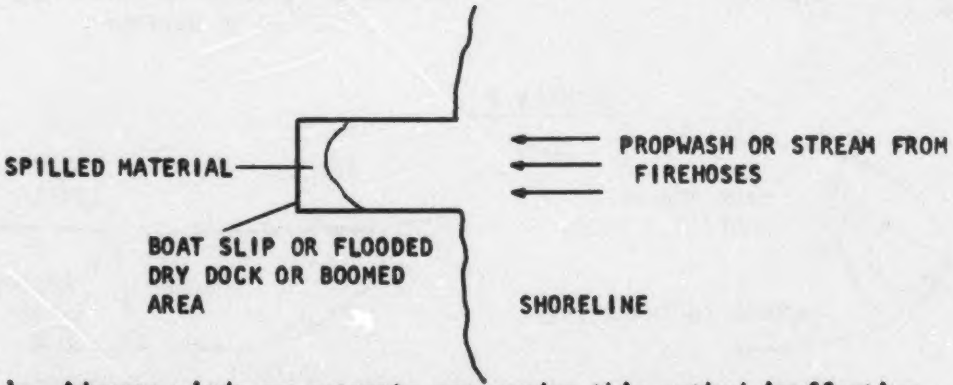
Figure 28 (continued)

I. WEIRS


WATER LEVEL
CONTAINED MATERIAL
WEIR
WATER LEVEL
WATER FLOW
RIVER BED

1. Weirs may be difficult to deploy properly.
2. Turbulence behind the weir may render this containment method ineffective.
3. To be effective the spilled material must be in the upper layer of water.

II. USING FIREHOSES OR PROPWASH TO DIRECT AND CONTAIN SPILLED MATERIALS

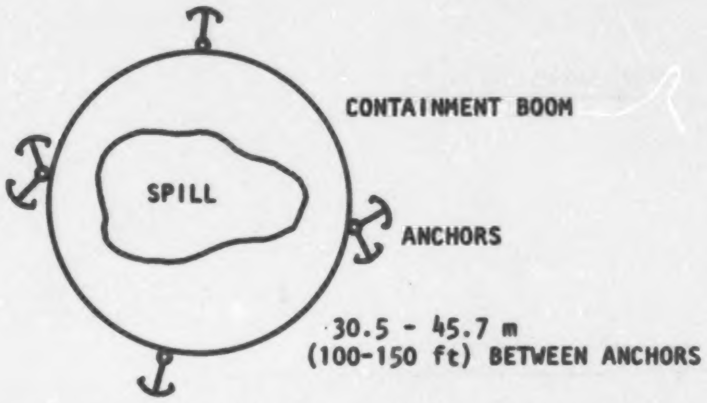

SPILLED MATERIAL
PROPWASH OR STREAM FROM FIREHOSES
BOAT SLIP OR FLOODED DRY DOCK OR BOOMED AREA
SHORELINE

1. Adverse winds or currents may render this method ineffective.
2. Firehoses or ships must be obtainable, and have access to the spill site.
3. A suitable containment area must be available.
4. Winds and currents must be taken into account.
5. Impact water with fire stream at least 6.1-9.2 m (20-30 ft) away from spill.

continued

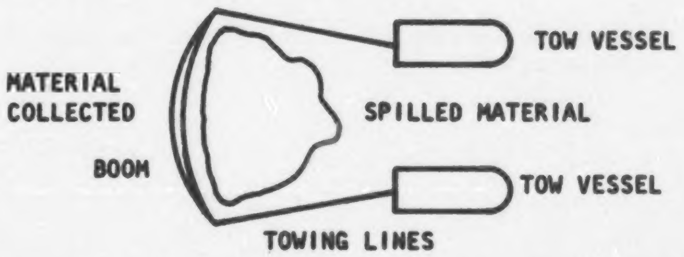
Figure 29. Containment of floating spills

III. ENCIRCLING BOOM


CONTAINMENT BOOM
SPILL
ANCHORS
30.5 - 45.7 m
(100-150 ft) BETWEEN ANCHORS

1. Heavy seas may render containment with this method ineffective.
2. Wind or current shifts may render this containment method ineffective.
3. The proper booms and deployment systems may be difficult to obtain.

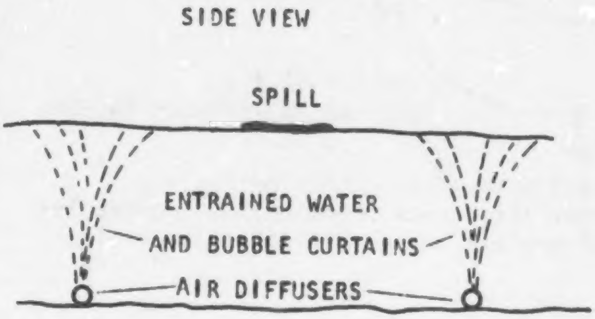
IV. COLLECTION AND TOWING OF A SPILLED MATERIAL WITH A BOOM

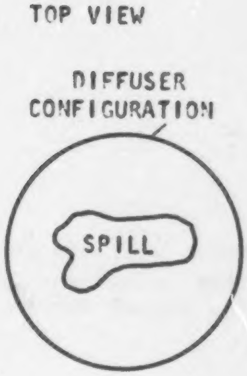

TOW VESSEL
MATERIAL
COLLECTED
SPILLED MATERIAL
BOOM
TOW VESSEL
TOWING LINES

1. Heavy seas may render containment with this method ineffective.
2. Wind or current shifts may render this containment method ineffective.
3. The proper booms and deployment systems may be difficult to obtain.
4. Towing speed may be limited to 2.8 km/hr (1.5 knots) or less.

Figure 29 (continued).

V. PNEUMATIC BARRIERS


SIDE VIEW
SPILL
ENTRAINED WATER
AND BUBBLE CURTAINS
AIR DIFFUSERS

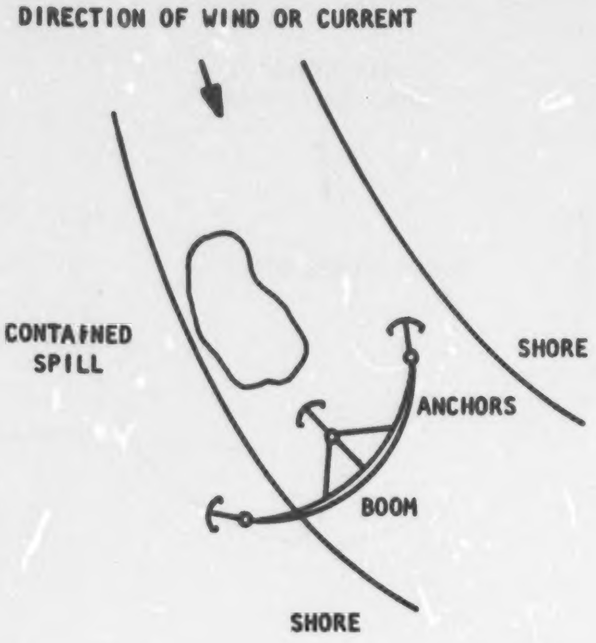

TOP VIEW
DIFFUSER
CONFIGURATION
SPILL

1. Wind or current may render this containment method ineffective.
2. Obtaining proper diffusers and compressors may be difficult.
3. Deep water requires suspension of diffusers in the water column to increase efficiency of unit.
4. Rarely used.

continued

Figure 29 (continued)

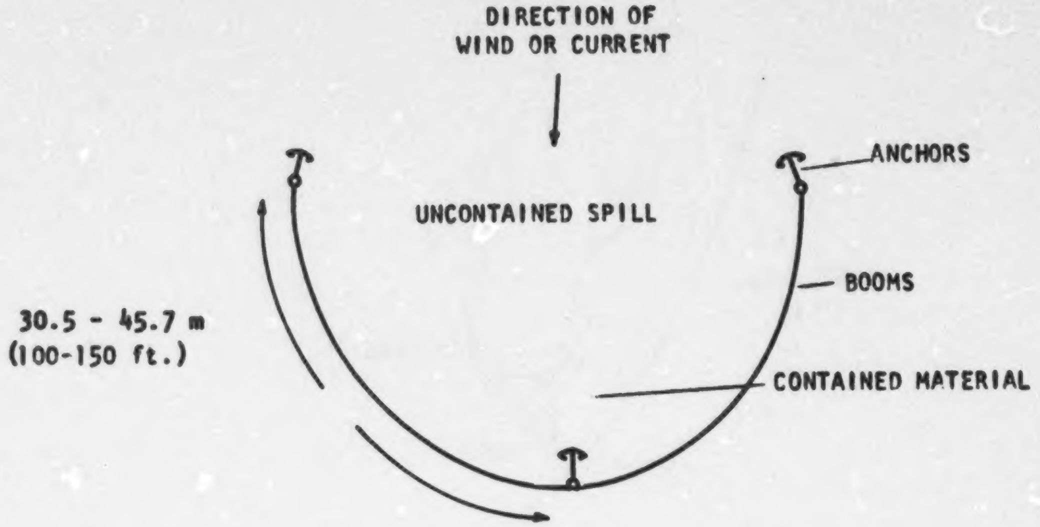
VI. DIVERSIONARY AND CONTAINMENT CONFIGURATION


DIRECTION OF WIND OR CURRENT
CONTAINED SPILL
SHORE
ANCHORS
BOOM
SHORE

1. Whenever possible use with outside bend and sufficient clearance to reach site.
2. An intermediate tie is needed to keep "bucket" from forming.
3. Technique is limited to currents up to 2.4-3.1 mps (8-10 fps)
4. Proper booms and deployment systems may be difficult to obtain.

Figure 29 (continued).

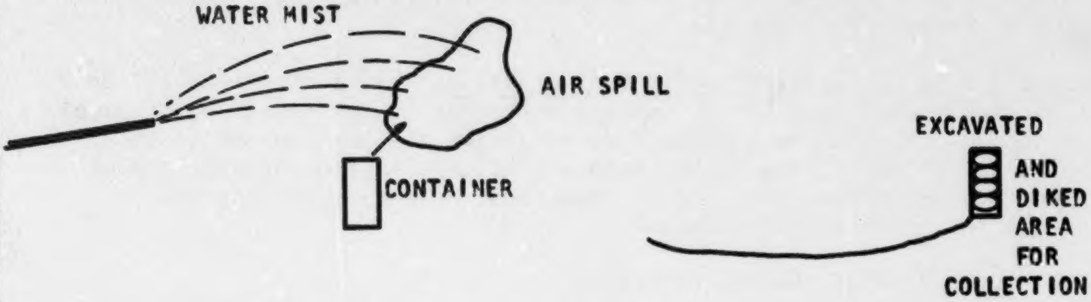
VI. DIVERSIONARY AND CONTAINMENT CONFIGURATION


DIRECTION OF WIND OR CURRENT
ANCHORS
UNCONTAINED SPILL
BOOMS
30.5 - 45.7 m (100-150 ft.)
CONTAINED MATERIAL

1. Heavy seas may render this containment method ineffective.
2. Wind or current shifts may render this containment method ineffective.
3. The proper booms and deployment devices may be difficult to obtain.
4. This technique is limited to currents up to 0.3-0.61 mps (1-2 fps).

Figure 29 (continued).

I. MISTING TO REMOVE CONTAMINANTS


WATER MIST
AIR SPILL
CONTAINER
EXCAVATED
AND
DIKED
AREA
FOR
COLLECTION

1. Not all materials will be removed in this manner.
2. Water source must be available.
3. Require large area for containment of resulting water.

Figure 30. Suppression of air spills

location. Specific information on containment methods is presented in the tables which follow. (Tables 17-21).

Step 7 Evaluate Choice - Once a preliminary selection has been made, the choice is evaluated by answering the list of questions (Figures 31-35) which are designed to indicate problems with the containment method. It is important to consider each of the questions individually and determine if any aspect of containment by that method is limiting. One question which must be answered regards the hazard effect of containing the material in a small space rather than allowing natural dispersal processes to remove it. The specific nature of the material, the size and type of the area affected, and the mobility of the system will aid in answering this question.

Step 8 Contain Safely if Indicated - The questions answered in Step 7 will then indicate if the chosen containment technique is feasible. Then the MOS must proceed cautiously, taking adequate safety precautions to contain the spill. Referral to more specific references regarding containment is necessary (Table 16).

Steps 9 & 10 Evaluation of Other Alternatives – If evaluation by Step 7 indicates containment by the initial technique is not feasible, other alternatives can then be evaluated to determine the best method of containment, if any. Once it has been established if the material can or cannot be contained, then the decision must be made regarding the succeeding spill handling method.

4.3 COLLECTION OF SPILLED MATERIALS

After containment, the spill may require collection for containment removal, or treatment. Various methods are available including those listed. More detailed information is available in other references.

a. Suction Skimmers - Remove surface contaminants by drawing layers through an orifice. The angle of the orifice establishes the ratio of water and contaminant to be removed (16).

b. Vacuum Skimmers - Remove floating materials also using a vacuum tank to generate the drawing force. Useful mostly for small spills or places where flammable materials are to be removed.

c. Sorbents - Used to collect floating material by distributing absorbents and then collecting them from the surface of the water body.

d. Dredging - Used to remove insoluble chemicals that are heavier than water. Various methods are used, however, care must be taken not to disturb the bottom and create a more hazardous situation (17).

TABLE 17. SPILLS ON LAND

Type	Application or Construction Method	Use	Advantages	Disadvantages
Dikes				
Earthen	Create with bulldozer or earth-moving equipment to compact earth (height depends on earth type)	Flat or sloped surface	1. Material on site 2. Construct with common equipment 3. Construct quickly	1. Natural permeability of soil 2. Seepage through ground 3. Surface composition of soil not suitable in all cases
Foamed Polyurethane	Use trained personnel to construct	Hard, dry surfaces	1. Hold up to several feet of water (3)	1. Leaks on wet ground 2. Hard to obtain dispersion device
Foamed Concrete	Use trained personnel to construct	Flat ground Slow moving spill	1. Better adhesion to substrates (clay/shale/grass)	1. Hard to obtain foam and dispersion device 2. Must set for a time period Will not hold high hydraulic heads (15)
Excavation	Bulldozer or earth-moving equipment - line if possible	Soft ground Natural cavitation	1. Material on site 2. Construct with common equipment	1. Move large amounts of material 2. Natural permeability of soil 3. Surface of soil not suitable in all cases
Excavation & Dikes	Bulldozer or earth-moving equipment - line if possible	Soft ground	1. Need less space than separate 2. Material on site 3. Construct with common equipment	1. Move large amounts of material 2. Natural permeability of soil 3. Surface of soil not suitable in all cases

TABLE 18. SPILLS IN WATER - HEAVIER THAN WATER SPILLS

Technique	Application or construction method	Use	Advantages	Disadvantages
Natural Excavations & Dikes	none	Where a natural barrier exists	No construction needed	Can't control the area which contains the spill
Construction of excavations & dikes	Dredges: hydraulic or vacuum pumps Divers with pumps then place concrete or sand bags around to form dike if bottom material is not sufficient	If bottom can be moved	Material is on site	1. Hard to construct 2. Stirred up bottom may cause dispersion and increased turbidity.

TABLE 19. SPILLS IN WATER - SOLUBLE OR MISCIBLE SPILLS

Method	Application or Construction Materials	Use	Advantages	Disadvantages
Sealed Booms	Boom Device to anchor	Contain depth limited volumes leaking containers	Contain entire depth of water	1. Deployment difficult 2. Not used for large bodies 3. Difficult to get good seal (16)
Diversion of Uncontaminated Flow	Earthmoving Equipment	Special area where topography is right	1. Can put cleaned water into diverted stream 2. Used for flowing water	1. Difficult to move large amounts of earth 2. Clear area needed 3. Impermeability of ground
Diversion of Contaminated Flow	Block entrance with sandbags, sealed booms or dikes	Special area where topography is right	1. Can put clean water back into stream 2. Used for flowing water	1. Difficult to move large amounts of earth 2. Clear area needed 3. Impermeability of ground 4. Adverse environmental impact
Gelling Agent (40)	Gels, Dispersion Devices; use experienced personnel	If small volumes	1. Stop flowing contaminant 2. Stop permeation	1. Hard to obtain 2. Can't use in large area 3. Must haul to dispose
Containment of Entire Waterbody	Diking Materials Earthmoving Equipment Sandbags, etc. Lining	For entirely contaminated area	1. Can allow containment of a large waterbody 2. Materials on site 3. Easily constructed	1. Not all waterbodies have containable overflow 2. Permeability 3. May be an unstable condition

TABLE 20. SPILLS IN WATER - FLOATING SPILLS

Method	Application or construction materials	Use	Reference*	Advantages	Disadvantages
Booms	Varies; need deployment device	Not too much current	CG-446-4 (41) p. 6-10 to 6-25	Used on large area; Many varieties	1. Only in waves less 2-4 feet 2. Current speed less than 0.7 knots
Weirs	Weir & boat	Calm	CG-446-4 (41) p. 6-25	Not easily clogged; Collects & contains	Not used in rough water
Pneumatic Barriers	Air compressor diffuser deployment method	Only shallow water	CG-446-4 (41) p. 6-25 to 6-25	Do not create a physical barrier to vessels	1. Not in rough water 2. Only shallow water 3. Only thin layers or materials
Spill Herding Methods	Chemicals on water spray or prop. wash	To protect shore or other facilities	CG-446-4 (41) p. 6-31 to 6-35	Useful in rough water	1. Not easily obtainable 2. Not 100% effective

* Many references are applicable; see Table 16.

TABLE 21. SPILLS IN AIR

Technique	Method	Use	Advantages	Disadvantages
Mist Knock down	Spray fine mist into air	Water soluble or low lying vapors	Removes hazard from air	Create water pollution problem and must be contained in solution
Fans or blowers	Disperse air by directing blower toward it	Very calm and sheltered areas	Can direct air away from populated areas	1. Not at all effective if any wind 2. Need large capacity of blowers 3. Hard to control

1. Will any natural phenomenon such as rainfall, soil or subsoil render the containment ineffective?
2. Will man-made conditions such as wells or underground drain tile render the method of containment ineffective?
3. Is there a sufficient quantity of containment material, personnel and equipment?
4. Can the containment method be deployed safely and effectively?
5. Can the spill be contained quickly enough by the proposed containment method?
6. At what point is the containment equipment likely to leak and how can the leaks be minimized or prevented?
7. Would another containment method be better?
8. Would the repercussion of containment be more harmful than the natural dispersal and/or breakdown of the spill?

Figure 31. Establishing the feasibility of spill containment on land

1. Are there any natural phenomenon such as bottom composition, current, wave action, access or water depth that would render the containment method ineffective?
2. Would man-made conditions such as shipping, concrete channels, or discharge of dams render the containment method ineffective?
3. Can a sufficient amount of containment materials, equipment, and personnel be deployed to the site safely?
4. Can the spill be contained quickly enough?
5. Will the spill leak or seep out of the proposed containment device? If so, can it be prevented from doing so?
6. Would another containment method be getter suited to the spill?
7. Would the repercussions of containment be greater than those of natural dispersion and/or breakdown?

Figure 32. Establishing the feasibility of containment for heavier than water spills

1. Are there any natural phenomenon such as discharge volume, spill volume, soil structure, bottom composition or rainfall that would render this containment method ineffective?
2. Will any man-made conditions such as dams, concrete channels, or bypasses render the containment methods ineffective?
3. Can a sufficient quantity of containment material, equipment, and personnel be obtained and deployed safely?
4. Can the spill be contained quickly enough by the proposed containment method?
5. Will leakage and seepage be a problem? If so, how can it be ameliorated or prevented?
6. Would any other containment method be better?
7. Would the repercussion of containment be greater than those of natural dispersion and/or breakdown?

Figure 33. Establishing the feasibility of containment for soluble spills

1. Will natural phenomenon such as wind, waves, current or tidal action render the containment device ineffective?
2. Is there any man-made condition, such as, periodic discharge from dams, water intakes, or boat traffic that would render the containment device ineffective?
3. Can a sufficient quantity of the containment device be obtained?
4. Can the containment device be deployed safely and effectively?
5. Can the spill be contained quickly enough by the proposed method?
6. At what point is the containment equipment likely to leak and how can the leaks be minimized or prevented?
7. Would another containment method be better?
8. Would the repercussion of containment be more harmful than the natural dispersal and/or breakdown of the spill?

Figure 34. Establishing the feasibility of containment for lighter than water spills

1. Will natural phenomenon such as wind or air current disperse the containment before containment is possible?
2. Can a suitable water collection setup be established?
3. Can the spill be approached safely?
4. Is the material removable by reaction with a water mist?
5. Would the repercussions of containment, especially in creating a water pollution problem, be more harmful than natural dispersal, taking adequate safety precautions?

Figure 35. Establishing the feasibility of air spill suppression

4.4 DECISION ON SPILL HANDLING

4.4.1 General

The critical decision regarding handling of the spill is very difficult. Many variables affect the decision, and these variables must be considered by the user and altered to fit the specific situation. Only then can the final conclusion be reached. There are four ways the spill can be handled: (1) diluted and dispersed into the natural environment, (2) treated "in-situ" with makeshift processes, (3) hauled to another site for disposal or treatment, and (4) treated in an on-site, but offstream, treatment system. The following items are presented to guide the thought processes of the OSC and allow him to decide on the best course of action for his situation.

4.4.2 Use of the Thought Guide

The thought guide (Figure 36) is a graphical presentation of the thought processes required of the OSC when establishing the handling of a spill. The boxed questions presented are merely summaries of many considerations which are to be answered by the OSC in establishing the final answer to the main boxed question. Once an answer of yes or no has been established, the arrows are followed to the box with the next applicable question. It is assumed that the OSC is familiar with the manual and can refer to the following sections which elaborate on the questions, if necessary. The result of the following thought guide will be determination of a feasible handling method for the specific spill situation.

4.4.3 Variables to Consider

Determining which of the four methods of spill handling should be used in a spill situation involves consideration of a series of questions which affect the choice of handling methodology. The following questions are outlined in Figure 36. This guide is flexible and is intended to aid the OSC but not to make the decisions for him. The following paragraphs outline the considerations which are necessary when the questions are to be answered.

1. **Is the spill contained or containable? - This information can be obtained by reference to subsection 4.2. The size and type of area affected, mobility of the spill and availability of containment methods are prime factors in this decision.**

2. **Is a remote treatment or disposal site available? - The answer is dependent on a wide variety of factors and a series of subquestions can be asked.**

   a. **Can the remote disposal site or treatment plant handle this material?**

   b. **Is the volume of the area affected by the hazardous material compatible with the capacity of the remote site?**

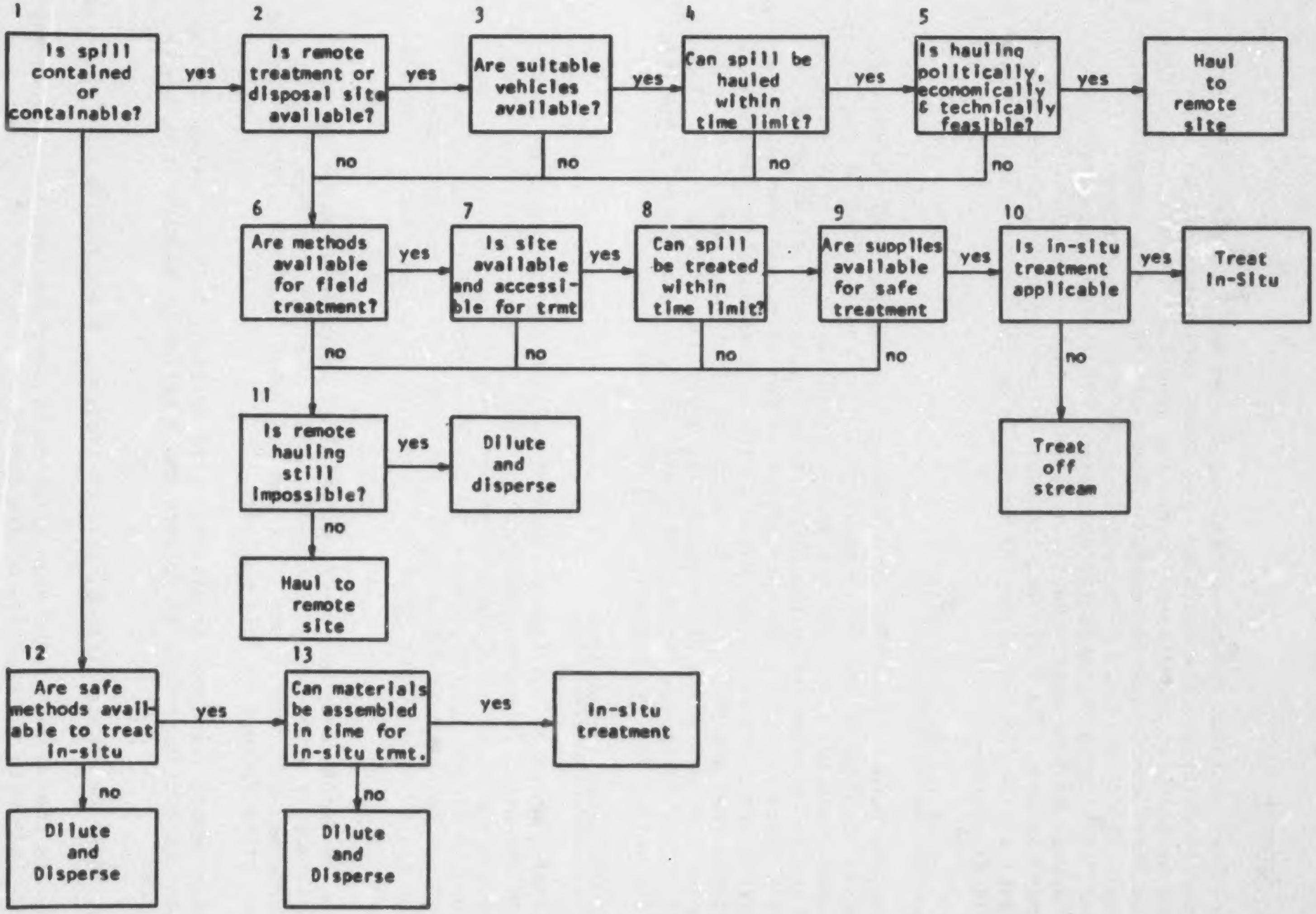

1
Is spill contained or containable?
yes
2
Is remote treatment or disposal site available?
yes
3
Are suitable vehicles available?
yes
4
Can spill be hauled within time limit?
yes
5
Is hauling politically, economically & technically feasible?
yes
Haul to remote site
no
no
no
no
6
Are methods available for field treatment?
yes
7
Is site available and accessible for trmt
yes
8
Can spill be treated within time limit?
9
Are supplies available for safe treatment
yes
10
Is in-situ treatment applicable
yes
Treat In-Situ
no
Treat off stream
no
no
no
no
11
Is remote hauling still impossible?
yes
Dilute and disperse
no
Haul to remote site
12
Are safe methods available to treat in-situ
yes
13
Can materials be assembled in time for in-situ trmt.
yes
In-situ treatment
no
Dilute and Disperse
no
Dilute and Disperse

Figure 36. Spill handling thought guide.

c. Can permission be obtained to use the site for treatment or disposal of the hazardous material and the affected media?

3. Are suitable vehicles available to haul the affected material?

The type of vehicle required is established by the chemical and physical characteristics of both the hazardous material and the affected media. Included in the considerations should be the following:

a. State of the material - liquid or solid or percent of each.

b. Corrosiveness of the material.

c. Proximity of sewer lines to allow disposal to a nearby treatment plant.

d. Other handling properties of the material at the given concentration.

4. Can the spill be hauled within a reasonable time limit?

This consideration includes the establishment of a reasonable time limit. This limit can be established by comparison to the length of time to set up and operate a treatment system for on-site treatment or by other means. If hauling is more time consuming, other handling methods should be considered. To establish the time for hauling, the following questions must be answered:

a. Is an unstable weather or physical condition establishing a time limit?

b. How far away is the remote site?

c. What is the volume of the material affected?

d. What is the truck capacity?

e. How many vehicles are available to haul materials each day?

f. How many and what capacity pumps are available?

The answers to these questions will allow the calculations regarding the total time required for hauling.

Example of determining if a spill can be hauled in a reasonable time:

Answers to questions - 4a-f:

a. 1 week (before a large rainstorm is expected).

b. 161 km (100 miles) (the distance to a remote treatment plant).

c. 3.78×10^5 liters (100,000 gal.) - volume of affected waterway

d. 8325 liters (2200 gal.) - available volume of septic tank truck

e. 5 trucks are available (number of trucks).

f. pump on truck 378 liter/min (100 gpm).

Time to fill and empty the truck.

$$\text{Time} = \frac{8325\ \text{l}\ (2200\ \text{gal.})}{378\ \text{l/m}\ (100\ \text{gpm})} = 22\ \text{min}$$

Total = 22 + 22 = 44 min.

$$\text{Travel time} = \frac{161\ \text{km}}{80.5\ \frac{\text{km}}{\text{hr}}}\ (50\ \text{mph}) = 2\ \text{hr}\ (120\ \text{min})\ \ (\text{one way})$$

Total = 120 + 120 = 240 min.

Total time + break (10% extra)

284 + 29 = 314 min/trip = 5.3 hr/trip.

Total number of trips required for all trucks

$$\frac{3.78 \times 105\ \text{l}}{8325\ \text{l/truck}} = \frac{(10^5\ \text{gal})}{(2200\ \text{gal/truck})} = 45.4\ \text{trips} = 46\ \text{trips}$$

How many hours to haul entire amount with 5 trucks?

$$\frac{46\ \text{trips/1 truck}}{5\ \text{trucks}} = 9.2\ \text{trips}$$

9.2 trips x 5.3 hours/trip = 29 hours

Therefore, 1 week has 168 hours and hauling can be accomplished within this time period with a large safety factor.

5. Is hauling politically, economically and technically feasible?

This question combines many of the non-specific variables which must be evaluated by the OSC. Political opinions may affect the decision regarding hauling by insistence on a specific and/or immediate course of action. This position may force the OSC to concur without further evaluation. Another aspect of hauling is the cost potential. The economics of both treatment and hauling must be evaluated with the following considerations in mind:

a. Concentration of the contaminant - The more concentrated the contaminant, the more likely that hauling will be the most effective method since treatment by-products may be as voluminous as the material treated.

b. Amount of solids produced - The amount of solids or sludges produced by treatment must be considered when evaluating the alternatives.

c. Amount of treatment by-products produced - The amount of spent by-products, such as carbon, produced must be considered prior to hauling.

d. Solids concentration of the wastewater - The total solids concentration of the wastewater may dictate that the entire volume be hauled, since these solids will already require disposal.

e. Expense of materials required for treatment - The cost of the materials required for treatment must be added to the cost of removing any treatment by-products or sludge produced.

f. Specific gravity and solubility of the materials spilled - The specific gravity will indicate if dredging or skimming operations can be used to remove the material and the solubility will indicate the concentration of the materials in a water body. In general, mostly insoluble floating or sunken materials can be hauled because of their high concentration, while soluble materials will usually require on-site treatment.

g. Location of material spilled - Generally, both land and air spills cannot be easily treated on-site due to the nature of the contamination. Once an air spill has been contained, hauling it to a manufacturer or other suitable location is generally the most practical arrangement. Land spills will contain high concentrations of both the contaminant and other solids, so hauling of the affected earth can be the most practical approach. Any rinse water which is used can then be captured and the hauling feasibility for it evaluated separately.

h. Size of the water body affected - Water spills must be evaluated separately since the effect on the amount of water affected and the effective concentration of the contaminant must be considered jointly. Basically, the volume and concentration establish the applicability of various treatment steps, and the hauling economics. Large concentrated spills are most difficult to handle because large hauling volumes will be generated both with and without treatment.

The technical aspects of hauling must also be considered. If the hauling is transposing the problem to a place where more effective treatment or control is possible, then hauling is feasible. However, if hauling merely transposes the problem without technical benefits, this approach may not be the best solution.

6. Are methods available for field treatment?

   This consideration is crucial when establishing the viability of treatment as an alternative handling method. There are treatment schemes presented in this document which establish methods for treating over 300 hazardous materials. OHMTADS, CHRIS, and other sources may include other treatment methods and should be consulted. If a treatment method cannot be found for a certain spilled material, the manufacturer can be contacted. If still no field applicable method is available, treatment on the scene is not an acceptable handling method.

7. Is the site available and/or accessible for treatment?

   There are certain size requirements that must be met when establishing a treatment site since an offstream plant requires at least 0.20 ha (0.25-0.5 acres) of area. In-situ treatment requires less area but accessibility to the spill location is important to allow delivery of necessary materials.

8. Can the spill be treated within a reasonable time limit?

   Treatment feasibility is also contingent upon the amount of time necessary to treat the wastewater. This time limit may be established by unstable weather conditions that would cause the spill to spread or by economic restraints caused by manpower costs. The following categories should be considered:

   a. Length of time to construct treatment process.

   b. Total flow through rate of operation.

   c. Total amount of material to be treated.

   d. Number of hours of operation per day.

   Example: a. 48 hours (to set up equipment).

   b. 189 l/min (50 gpm) (flow rate through plant).

   c. 3.78×10^6 l (10^6 gal.) (amount of water to treat)

   d. 16 hours/day (hours of daily operation)

$$\text{Total time} = \left[48 \text{ hrs} + \left(\frac{3.78 \times 10^6 \text{ l}}{189 \text{ l/min} \times 60 \frac{\text{min}}{\text{hr}}}\right)\right] \frac{1}{16 \text{ hr/day}} = 24 \text{ days}$$

9. Are supplies available for safe treatment?

Included in the considerations for this question are: The volume and cost of supplies; the length of time for delivery; and the materials necessary for safe handling of chemicals. If any of these considerations indicate proper materials are not available, the answer to the main question is considered negative.

10. Is in-situ treatment applicable?

At first inspection, in-situ treatment would seem to be the best method of treatment for the following reasons:

a. Handling of the hazardous material is minimized.

b. Construction time and land requirements are substantially reduced or eliminated.

c. Treatment can be done on the entire system at once.

In certain situations such as where efficient treatment is not necessary, when the time to treat is not critical, when the water volume is extremely great or when no significant amounts of byproducts are produced, in-situ treatment becomes more advantageous. However, it is necessary to evaluate the end products of the process and consider other aspects on in-situ treatment before it is implemented. Important considerations include:

a. Can in-situ treatment methods achieve the degree of treatment required?

b. Are significant amounts of sludge produced which may either harm the benthic population or require additional removal?

c. Can in-situ treatment accomplish the task in a reasonable amount of time or would an offstream process be faster?

d. Are dangerous by-products formed or is there a general change in the water chemistry which is harmful to existing fauna and flora?

e. Is the method safe for personnel employing it?

Once these factors have been considered, the choice of treatment type can be made.

11. Is remote hauling still impossible?

This question provides for re-evaluation of the hualing question. At this point, it is assumed that on-site treatment either in-situ or offstream is not possible due to negative answer to any one of

Questions 6-10. Therefore, the feasibility of hauling as indicated by Question 5 must be re-evaluated. It is best to reconsider all the questions (2-5) to determine the hauling feasibility. If this question still results in a negative answer, dilution and dispersal is the only alternative left.

12. Are safe methods available for "in-situ" treatment?

    This question initially assumes that the spill is not contained or containable. Then the methods for in-situ treatment must be considered. Both flow-through and "batch" methods and the effects of these procedures and their by-products must be established. Among the pertinent questions are:

    a. Is a reasonable in-situ method available? When in-situ treatment is not possible, dilution and dispersion is the only available handling technique.

    b. Is the treatment effective to achieve desirable removals?

    c. Are by-products produced which are harmful to the aquatic environment?

    d. Can the materials be assembled in time for in-situ treatment? This is a critical immediate concern for an uncontained spill. Both the specific chemicals or chemical products and the construction material must be obtained in a short time to determine if in-situ treatment is feasible. Where this is not possible, dilution and dispersal must be used.

4.5 HANDLING A SPILL BY HAULING

Once the decision has been made to haul a spill the following specific information must be gathered by the OSC:

1. Determine the hazard potential and corrosivity - the specific problems in handling are outlined in many handbooks and any special equipment must be obtained.

2. Calculate the total volume of material to be handled.

3. Obtain suitable hauling vehicles:

    Liquid spill: septic tank truck
    tank truck
    railroad tank car
    empty barge
    cargo ship

Solid spill: sealed dumpster (small volume)
lined and covered dump truck
lined and covered railroad cars

4. Obtain pumping or transfer equipment and estimate the rate of transfer of material.

5. Estimate the total time to haul the entire spill:

The calculations are summarized as follows:

$$\frac{\text{Total spill volume}}{\text{Volume of 1 truck}} = \text{Number of truck loads}$$

$$\frac{\text{Number of truck loads}}{\text{Number of trucks}} = \frac{\text{Number of loads}}{\text{1 truck}}$$

$$\frac{\text{Volume of 1 truck}}{\text{Loading Rate (pump etc.)}} \times 2 = \frac{\text{Number of loads}}{\text{1 truck}}$$

$$\frac{\text{Travel distance}}{\text{Highway speed}} \times 2 = \text{Travel Time}$$

$$1.1\ \text{(Travel time \& fill and draw time)} = \text{Total Time/Load}$$

$$\text{Total time/load} \times \text{Number of loads/truck} = \text{Total time/truck}$$

$$\frac{\text{Total time}}{\text{truck}} + \text{Fill time} \times \text{Number of trucks} = \text{Total time to haul}$$

(assuming staggered fills)

4.6 HANDLING BY DILUTION AND DISPERSAL

Only after all other possible alternatives have been investigated and found not to be feasible is the method of handling by dilution and dispersal to be considered. This method must be used only as a last resort to minimize local hazards. Care must be taken to determine if this method is feasible in that mixing the hazardous chemical with water does not cause undesirable side reactions or by-products. Once it has been determined that dilution and dispersal is the only action available, then additional water sources must be brought to the spill site. Water should be added to the stream at a turbulent spot to allow complete mixing with the hazardous material. Care should be taken not to exceed the capacity of the water body and extend the hazard past its natural boundary. Dispersion can also be induced by creating mixing zones in the waterway and reducing the pockets of concentrated contaminant which may exist.

4.7 HANDLING BY TREATMENT ON SITE

4.7.1 General

Once it has been established that treatment of the spill on-site is the most feasible approach, then the method of treatment must be chosen. At the present time most in-situ treatment methods are experimental and therefore, have not been included as part of this review of state-of-the-art processes. The emphasis instead has been placed on construction of offstream processes and therefore leads directly into Chapter 5.

Unit processes have been chosen that have features applicable to jury-rigged construction. The possible processes were evaluated according to the following criteria:

1. They should be capable of being set up in one to two days, and therefore, must be constructed of readily available materials, and should be of simplified construction.
2. They should not require large amounts of power or other supplies.
3. They should be flexible and capable of operating under a wide variety of conditions.

Many types of wastewater treatment systems were considered and 5 were chosen: filtration, carbon adsorption, ion exchange, gravity separation and chemical reaction (oxidation/reduction, neutralization and precipitation).

The processes will be integrated into a parallel batch system which allows the flexibility and simplified operation of a batch process and yet almost continuous operation

4.7.2 Specific Treatment Schemes

Treatment schemes have been suggested for the 303 chemicals indicated on EPA's modified list of hazardous chemicals (18). It must be emphasized that the schemes have not been field tested and extreme care must be taken in their application. The information regarding the schemes indicated in this chapter was developed from several different references, common industrial waste treatment schemes and the experience of personnel familiar with chemical wastewater treatment. The schemes are intended to direct the people but may not be applicable in all situations. The following considerations were used in developing the treatment schemes:

1. The chemicals are assumed to be relatively pure and free of major chemical interferences during treatment.
2. All schemes are established to handle chemicals in an aqueous system and in water.
3. The dosages of treatment chemicals needed will be established by on-site

testing of a sample of contaminated water. These field tests will also aid in establishing problems which may occur during field treatment.

4. Gravity separation was included as a requirement or an option in all shcemes. This separation process should always be considered since it will reduce the chemical demand of the waste and allows a natural concentration of contaminants.

5. Filtration is included as an additional clarification step to allow carbon adsorption and ion exchange processes to operate more efficiently.

6. Filtration is also used to remove the fine suspended materials after certain precipitation reactions which require highly efficient removals (19,20).

7. Additional pretreatment requirements such as a presettler or filtration must be evaluated by the user.

8. The schemes indicate batch processes in series, however, sometimes more than one process can be done in the same tank. This is usually true when no sludge is produced in the reaction. However, if a sludge is produced, series tanks are necessary to avoid negating the effects of the previous operation.

The final consideration for all treatment schemes is determining if the treatment is complete and discharge is acceptable. The effluent quality achieved by a certain schematic is dependent upon many variables including strength of the waste, chemical interferences in the water body, etc., and cannot be predicted before a spill event. The discharge concentration level must be established depending upon the individual spill situation and the effluent must be tested prior to its release into the surrounding waters. Depending on the complexity of the analytical method required and the proximity of capable laboratories, it may be necessary to hold the effluent from the process for a certain time period. Therefore, extra tanks must be supplied to provide the necessary detention. These tanks must have a capacity which will equal the amount of flow that can be treated during the duration of analytical test, plus the amount treated during the time it takes to empty one of the tanks, plus the amount treated during the time it takes to fill one of the tanks. Obviously, a higher number of smaller volume tanks will result in less total tank volume required. The number of tanks can be calculated as follows:

$$\text{Number of tanks} = \frac{\text{Volume treated during analytical period}}{\text{Volume of tank being used}} + 2$$

The treatment schemes as shown in Table 22, convey specific information about the treatability of the 303 hazardous compounds. Each column in the table conveys specific information which is discussed below:

Column I - Name of Compound   One of the 303 hazardous materials.

Column 2 - Amenability to Treatment in a Municipal Treatment Plant - This indicates whether the material can be discharged to a municipal treatment plant without creating major upset. The specific plant operator must be consulted before a final decision can be made.

Column 3 - Treatment Scheme - This column indicates the applicable treatment scheme and options for each chemical. The symbols used are defined as follows:

○ - Batch Process

□ - Flow Through Process

╌╌╌ - Optional Process

——— - Recommended Process

$\boxed{A}$ - Carbon Adsorption

F - Dual Media Filtration

$\boxed{IX}$ - Ion Exchange

(CR) - General Chemical Reaction

Ⓡ - Reduction

Ⓞ - Oxidation

Ⓢ - Gravity Separation

Ⓟ - Precipitation

Ⓝ - Neutralization

$H_2 \downarrow O$ - Dilution

The treatment chemicals are indicated by arrows into the specific unit processes and as indicated previously, more than one process may be done in one tank.

Column 4 - Treatment Specifications The endpoints for determining chemical dosages are briefly indicated.

Column 5 - Comments	This gives additional information which may be helpful to the user. This may include specific hazards or methods to simplify treatment.
Column 6 - References	The reference column is intended to allow the user to have more information regarding treatment schemes or the bases of the schemes as presented. It must be recalled that the processes have not been field tested and care must be taken in their application. In some cases an asterisk (*) has been included which indicates that the process as described are theoretically possible but no reference was available which could verify the technique. Additional care must therefore be taken when performing bench scale tests and effluent analyses are critical.
Column 7 - Provisional Limit	The provisional limit defines acceptable levels of exposure of the working and general population and ecology (19). The levels are very conservative so the OSC must remember to take into account dilution by the natural water body which may allow the effluent level to be many times higher than that listed. This limit is intended as a guideline, however, the best procedure is for the user to establish the acceptable discharge level for the specific material by consulting local authorities. This

number is not indicative of
the effluent quality
established by the treatment scheme.

Once the chemical has been located on the table, the user can then use the information to determine the amount of chemicals or materials needed for treatment. The treatment specifications and bench tests will allow the user to calculate the amount of chemicals to order.

The carbon amounts are indicated in weight of carbon per weight of soluble material. Therefore, to calculate the total amount of carbon, the solubility of the spilled chemical and the volume of water affected must be known. The carbon amounts ordered should be based on the highest number in the range presented. Then as the carbon is spent during treatment, the volumes should be checked to determine if more carbon is needed. The numbers given were divided into various ranges depending on many factors including adsorbability, toxicity and solubility. The following assumptions were made in establishing the values presented:

1. To reach low levels, much more carbon is needed even for strongly adsorbed materials.

2. All insoluble material will be removed by sedimentation and filtration prior to the carbon column.

3. Carbon demand by other organics is not great.

4. Compounds with low solubility and high toxicity will be treated to low contaminant levels and require high carbon doses.

5. Less toxic materials will not require low efficient concentrations so less carbon is needed.

It is very difficult to attain both effective contact time and control of carbon columns in the field, so a series operation is recommended. Samples can then be taken between the two columns to predict when breakthrough will occur. The columns should also be operated countercurrently to allow most effective removal of the contaminant.

To use Table **22** effectively, the following procedures should be followed:

1. Turn to the specific chemical name which is to be treated.

2. Establish the possible treatability through disposal to a sewage treatment plant.

3. If disposal to the sewer is not feasible, go on to determine the appropriate treatment scheme.

4. Note the treatment specifications and comments which apply to the spill situation.

5. Go to specific references to collect additional information if necessary.

6. Turn to individual sections on process descriptions and perform outlined bench scale tests.

7. Calculate and order amount of chemicals and other material needed as outlined.

8. Start process construction by reference to the system design, Chapter 5 & 6.

4.7.3 Treatment of Mixtures

The treatment schemes as presented in Table 22 deal with individual hazardous chemicals and to not specifically consider the numerous problems associated with treatment of mixtures. If a spill of mixed chemicals has occurred,extra care must be taken during all steps of identification, assessment,and treatment. The following procedures should be followed:

1. If the identity of one or more of the chemicals spilled is not known, do not approach the spill site.

2. If the identity of the chemicals is known, determine the compatibility of the spilled compounds. To do this, make preliminary reference to the compatibility chart included in Table 10. Then contact the chemical's manufacturer or local University Chemistry department for more information.

3. Establish the identity and amount of reaction products from the above sources or reference to chemical handbooks.

4. Choose a possible treatment scheme to remove the reaction product or reactant. Removal of the product or reactant should force the equilibrium of the reaction in the desired direction. However, the treatment scheme chosen should be verified with the consulting chemical authority.

TABLE 22. SUGGESTED TREATMENT SCHEMES

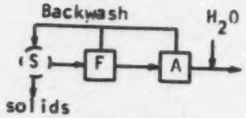
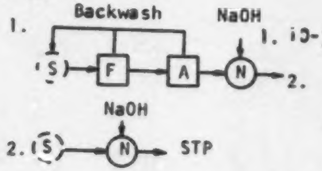
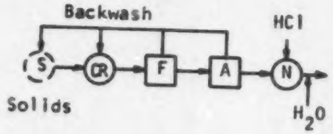
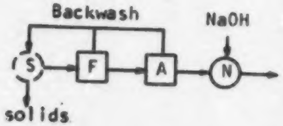
Chemical	Amenable Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Acetaldehyde	When diluted		C:35-100 #/# Sol. Matl.	Dilute if necessary/ compound may volatilize	10,19 21,22	9.0
Acetic Acid	When neutralized and diluted	 1. Backwash NaOH S F A N 2. NaOH 2. S N STP	1. 10-35 #/# Sol. Matl. 2. Neutralize with NaOH to pH 7/send to STP.	Neutralize and send to STP if possible/otherwise treat with carbon/ion exchange may also be used	10,19 21,22	1.25
Acetic Anhydride	When neutralized and diluted	See Acetic Acid		Reacts with water to form Acetic acid	10,19	1.0
Acetone Cyanohydrin	May require acclimatization	 Backwash HCl S CR F A N Solids H_2O	Neutralize with NaOH to pH 8.5 Adsorb/neutralize to pH 7. C:10-100 #/# Sol. Matl.	Raise pH to suppress cyanide gas formation but not greater than pH 9	10,19	2.0
Acetyl Bromide	When diluted		After Adsorption add NaOH to pH 7. C:10-100 #/# Sol. Matl.	Dredge pump or vacuum undissolved from bottom. Decomposes to form Br_2 and HBr	10,19	0.05
Acetyl Chloride	When diluted	See Acetic Acid		Reacts with water to form acetic acid and HCl	19	0.05

TABLE 22. (continued)

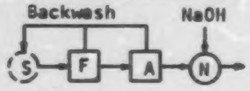
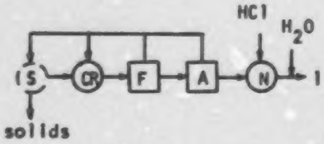
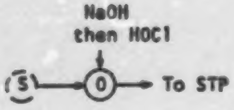
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Acrolein	When neutralized dilute/acclimated system desirable		C:10-100 #/# Sol. Matl. then NaOH or other base to pH 7.	Can oxidize and route to STP if possible (use air) - extremely poisonous and explosive	10, 19	0.01
Acrylonitrile	When diluted/ may need to be acclimated	1.  2. 	1. Add NaOH to pH 8.5/adsorb/ neutralize to pH 7 with HCl C: 10-100 #/# sol. matl. 2. Add NaOH to pH 10 then add HOCl to a residual react 30 min./ discharge to STP	Liquid is flammable and explosive - Careful to avoid HCN evolution or direct contact with NaOH. Option 2 produces cyanates which are less toxic	10, 19	2.0
Adipontrile	When diluted and acclimated	See Acrylonitrile			19	1.25

TABLE 22. (continued)

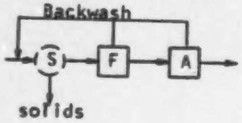
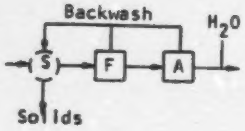
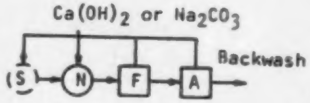
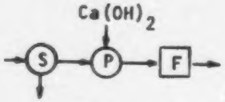
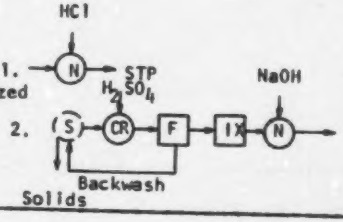
Chemical	Amenable Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Aldrin	No		C: 100-300 #/# sol. matl.	Vacuum dredge or pump undissolved portion from bottom (if wettable powder) skim if wettable oil	10, 19	0.012
Allyl Alcohol	When diluted		C: 35-100 #/# sol. matl.	Discharge to treatment plant if feasible; may require dilution after adsorption	10, 19	0.23
Allyl Chloride	When diluted and acclimated		Add $Ca(OH)_2$ to pH 6-7/ adsorb and discharge C:10-100 #/# sol. matl.	Highly flammable; hydrolyzes to allyl alcohol in aqueous solution; however, since slow to dissolve, use boom or sorbants if slick exists	10, 19, 23	0.15
Aluminum Sulfate	When diluted		Add $Ca(OH)_2$ to pH 6-7/filter and discharge	Hydrolyzes in water to reproduce aluminum hydroxide (white) precipitate/add polyelectrolyte if needed for settling	10, 19, 24	250 (as SO_4)
Ammonia (in water aqueous ammonia or ammonium hydroxide)	When diluted (and neutralized if necessary)	 1. HCl N STP 2. H_2SO_4 NaOH S CR F IX N Backwash Solids	1. Neutralize to pH 7 with HCl 2. Add H_2SO_4 to pH 6-7/exchange/ neutralize to pH 7	Ammonium will exert oxygen demand on receiving body unless removed or oxidized. Adjusting pH to 6 insures formation of NH_4^+ if needed for resin.	10, 19, 25	0.01

TABLE 22. (continued)

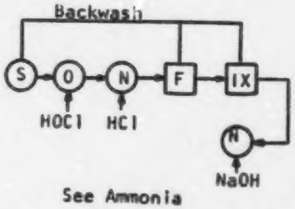
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Specifications	Comments	Reference	Prov. Limit mg/l
Ammonium Acetate	if neutralized	See Ammonia		Dilute discharge to reach acceptable acetate levels	10,19,25	0.01 (NH_3)
Ammonium Benzoate	if neutralized	See Ammonia		Dilute discharge to reach acceptable benzoate levels	10,19,25	0.01 (NH_3)
Ammonium Bicarbonate	if neutralized	See Ammonia			10,19,25	0.01 (NH_3)
Ammonium Bisulfite	if neutralized & oxidized	 Backwash S O N F IX HOCl HCl N NaOH	Add HOCl to a residual/ react 10 min/neutralize to pH 7 w HCl/filter/ place through ion exchange media/add NaOH to pH 7 if needed	Oxidation can occur before ammonium removal/ if STP available, discharge there	10,19,25	0.01 (NH_3)
Ammonium Bromide	if neutralized	See Ammonia		Dilute discharge to reach acceptable bromide level	10,19,25	0.01 (NH_3)
Ammonium Carbanate	if neutralized	See Ammonia		Dilute to reach acceptable carbonate level if necessary	10,19,25	0.01 (NH_3)
Ammonium Carbonate	if neutralized	See Ammonia		Dilute to reach acceptable carbonate levels	10,19,25	0.01 (NH_3)
Ammonium Chloride	if neutralized	See Ammonia		Dilute to reach chloride discharge levels if necessary	10,19,25	0.01 (NH_3) 250 (Cl^-)

TABLE 22. (continued)

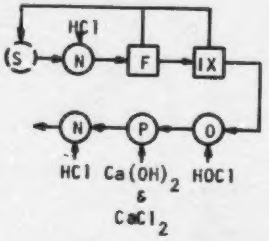
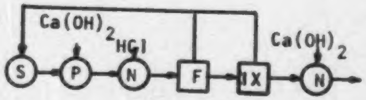
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Specifications	Comments	Reference	Prov. Limit mg/l
Ammonium, citrate-	if neutralized	See Ammonia		Dilute if necessary	*	
Ammonium Fluoroborate	unknown	No treatment scheme recommended at this time			*	
Ammonium Hydroxide	if neutralized	See Ammonia			10,19,25	0.01
Ammonium Hypophosphine	if neutralized & oxidized	 HCl S N F IX N P O HCl Ca(OH)$_2$ & CaCl$_2$ HOCl	Add HCl to pH 7/filter & exchange in weakly acidic media/oxidize to HOCl residual/add Ca(OH)$_2$ and some CaCl$_2$ to pH 11/neutralize to pH 7	Removal of phosphate should occur after exchange to avoid removing excess cations from solution/CaCl$_2$ will allow sludge volume to be reduced by adding Ca(OH)$_2$ if more ppt/continue until no ppt forms	10,19,25	0.01 as NH$_3$
Ammonium Iodide	if neutralized	See Ammonia		Dilute or reach acceptable iodide concentration	10,19,25	0.01 as NH$_3$
Ammonium Nitrate	if neutralized	See Ammonia		Dilute or remove with anionic exchange resin	10,19,25	0.01 as NH$_3$
Ammonium Oxalate	if neutralized	 Ca(OH)$_2$ HCl Ca(OH)$_2$ S P N F IX N	Add Ca(OH)$_2$ to pH 9/ppt oxalate/neutralize w HCl to pH 7/filter exchange/neutralize with base to pH 7	Oxalate should be removed in the lime precipitation step	10,19,25	45 as NH$_3$

TABLE 22. (continued)

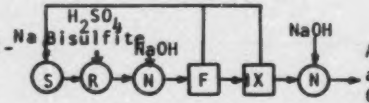
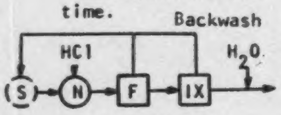
Hazardous Chemical	Amenable to ~iological Trmt. at Municipal STP	Treatment Scheme	Specifications	Comments	Reference	Prov. Limit mg/l
Ammonium Pentaborate	When neutralized and dilute	See Ammonia		Dilute to reach acceptable Pentaborate levels.	10,19,25	0.01 as NH_3
Ammonium Persulfate	When neutralized and dilute	 Na Bisulfite H_2SO_4 NaOH NaOH S R N F X N	Add H_2SO_4 to pH 3/ add bisulfite to large ORP change or indicator change/neutralize to pH 7/filter exchange neutralize to pH 7 with NaOH often.	Special indicator is Methylene Blue in 50% solution of Zinc Acetate - add 0.5ml to 1 drop of test solution/stays violet until persulfate is gone - when color is not violet reaction is done - test often.	26	0.01 as NH_3
Ammonium Silicofluoride	Unknown	No treatment scheme recommended at this time.				
Ammonium Tartrate	When neutralized and dilute		Add HCl to pH 7/ filter/exchange/ carbon can be used to remove tartrate	Dilute to meet tartrate standards on carbon	10,19,25	0.01 as NH_3
Ammonium Thiocyanate	When neutralized and dilute	See Ammonia		If desired, thiocyanate can be oxidized further with HOCl.	10,19,25	0.01 as NH_3
Ammonium Thiosulfate	When neutralized and dilute	See Ammonia		Dilute if necessary	10,19,25	0.01 as NH_3

TABLE 22. (continued)

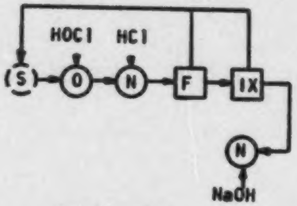
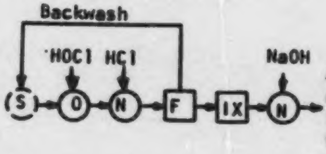
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Specifications	Comments	Reference	Prov. Limit mg/l
Ammonium Sulfamate	When dilute and neutralized		Chlorinate w HOCL to residual/react 5 min./neutralize to pH 7 if needed/filter/exchange in weakly acidic resin neutralize to pH 7 with NaOH.	Sulfamate must be removed prior to ammonia trmt. since it converts to NH3 and H_2SO_4 when oxidixed.	10,19,25	0.01 as NH_3
Ammonium Sulfate	When neutralized	See Ammonia		Dilute if necessary to meet sulfate discharge levels	10,19,25	0.01 as NH_3 250 as SO_4
Ammonium Sulfide	When oxidized and neutralized	 Backwash HOCl HCl NaOH S O N F IX N	Add HOCl to residual react 5 min./neutralize to pH 7 with HCl/filter/exchange on weakly acidic resin/neutralize to pH 7 with NaOH.	Take care to avoid inhalation of H_2S-a self contained breathing apparatus is recommended.	10,19,25	0.75 as H_2S
Ammonium Sulfite	When oxidized and neutralized	See Ammonium Sulfide			10,19,25	0.01 as NH_3 0.10 as Sulfate

TABLE 22. (continued)

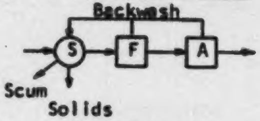
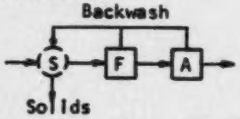
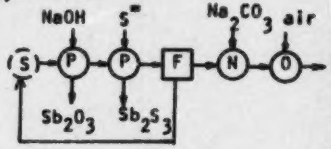
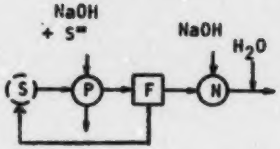
Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Amyl Acetate	When diluted		C: 10-100 ### sol. matl.	Remove floating portion asap; soluble to 850 ppm. Dilution & discharge may be feasible	10,19	26.3
Aniline	When diluted with time for seed acclimation (activated sludge)		C: 1-10 ### of sol. matl.	Slightly heavier than water so dredging may be necessary. Produces poisonous gas if heated	10,19,27	0.95
Antimony Pentachloride	Not unless treated first	 NaOH $S^=$ Na_2CO_3 air S P P F N O Sb_2O_3 Sb_2S_3	Add NaOH to pH 7/ ppt oxide/then saturate w/$S^=$ to residual/settle/ filter/neutralize w/soda ash -pH 7/ aerate to remove excess $S^=$	Chlorine gas may be formed from this compound. Be careful not to add excess $S^=$ and produce H_2S toxic gas	1,10 *	0.05 (as Sb)
Antimony Pot. Tartrate	Not unless treated first		Add NaOH to pH 7/ ppt oxide/then saturate with Na_2S to residual/ settle/filter/neutralize to pH 7. Aerate if necessary.		9	0.05 as Sb

TABLE 22. (continued)

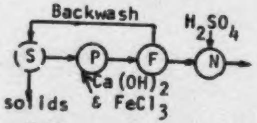
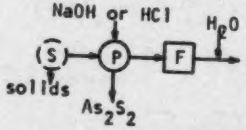
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Antimony Tribromide	no	See Antimony Pentachloride		Check to insure acceptable bromide level in discharge	10,19,20	0.05 as Sb
Antimony Trichloride	no	See Antimony Pentachloride		Check to insure acceptable chloride level in discharge	19,26	0.05 as Sb
Antimony Trifluoride	no	See Antimony Pentachloride		Check to insure acceptable fluoride level in discharge	19,20	0.05 as Sb
Antimony Trioxide	no	Same as Antimony Pentachloride			19,26	0.05
Arsenic Acid	no	 Backwash S P F N H_2SO_4 solids $Ca(OH)_2$ & $FeCl_3$	Add lime to pH 10.5 then add $FeCl_3$ to form floc/settle & filter/neutralize.	Arsenic acid converts to Arsenate in water with O_2 present/will be caught with ferric hydroxide & removed	20*	0.05 as As
Arsenic Disulfide	no	 	Change pH to 6-7 and allow As_2S_2 to precipitate/filter & dilute if necessary	Dredging may be required since As_2S_2 is quite insoluble. Add $FeCl_3$ and alum to aid clarification	20,24	0.05 as As
Arsenic Pentaoxide	no	See Arsenic Acid		Dredge undissolved portion from bottom if necessary	20	0.05 as As

TABLE 22. (continued)

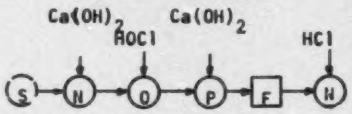
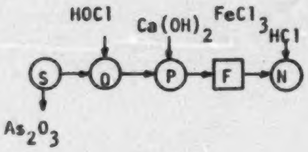
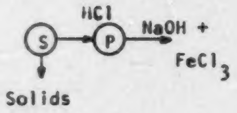
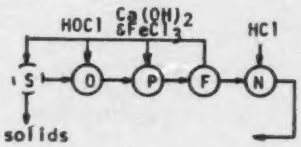
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Arsenic Trichloride	no	 Ca(OH)$_2$ HOCl Ca(OH)$_2$ HCl S N O P F N	Neutralize to pH 7. Add HOCl to res./add more Ca(OH)$_2$ to pH 10.5 and FeCl$_3$ to floc/filter if needed neutralize.	Evolves HCl in water. Soda ash or bicarbonate can be used to suppress HCl evolution	19,20*	0.05
Arsenic Trioxide (As$_2$O$_3$)	no	 HOCl Ca(OH)$_2$ FeCl$_3$ HCl S O P F N As$_2$O$_3$	Settle/add HOCL to residual. Add lime to pH 10.5 + FeCl$_3$ to floc/filter neutralize to pH 7.	Dredge pump or vacuum precipitate from bottom	10,19,20	0.05 as As
Arsenic Trisulfide	no	 HCl S P NaOH + FeCl$_3$ Solids	Change to pH 6-7 and then allow As$_2$S$_3$ to ppt/Add FeCl$_3$ to ppt.	--	10,19,20	0.05 as As
Calcium Arsenate	no	Same as Arsenic Acid			20	0.05 as As
Calcium Arsenite	no	 HOCl Ca(OH)2 &FeCl3 HCl S O P F N solids	Adjust pH to 5-9, oxidize w/HOCl to residual/add Ca(OH)$_2$ to pH 10.5/add FeCl$_3$ to floc/settle/filter/ neutralize to pH 7/discharge.	The arsenite is oxidized to arsenate which is treated as before.	20	0.05 as As
Potassium Arsenate	no	See Arsenic Acid			20	0.05 as As

TABLE 22. (continued)

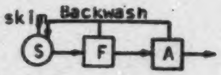
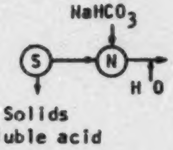
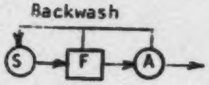
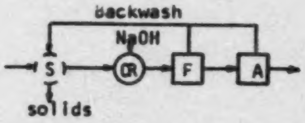
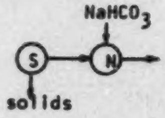
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Potassium Arsenite	no	See Calcium Arsenite			10,19,20	0.05 as As
Sodium Arsenate	no	See Arsenic Acid			20	0.05 as As
Benzene	When diluted	 skim Backwash S F A	C:10-35 ### sol. matl.	Skim off surface if possible.	10,29	3.5
Benzoic Acid	When diluted	1.  NaHCO3 S N H O Solids insoluble acid 2.  Backwash S F A	1. Add $NaHCO_2$ to pH 7 after sedimentation has removed most insolubles. 2. C:10-35 ### sol. matl.	Dilute waste w/water to allow discharge into water body after neutralization. Carbon may be used to remove contaminant	19	1.25
Benzonitrile	no	 Backwash NaOH S CR F A solids	C:35-100 ### sol. matl. Adjust pH to 8.5 to suppress HCN formation	Overnight holding may be required to insure complete reaction.	28	0.01 As CN
Benzoyl Chloride	After with NaOH	 NaHCO3 S N solids	Add bicarbonate to pH 7-8; Adsorb on carbon.	Send to STP if possible/if removal needed adsorb on carbon. C:10-100 ### sol matl.	19,28	0.45

TABLE 22. (continued)

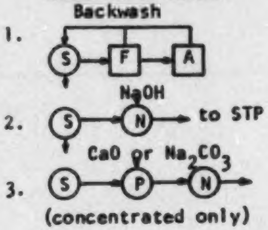
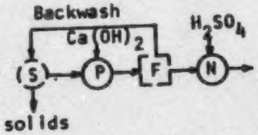
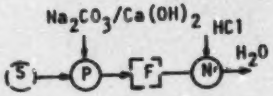
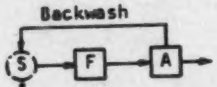
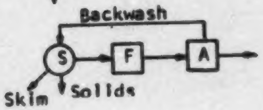
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Benzyl Chloride	Use NaOH to convert to alcohol; then biodegradable	 Backwash 1. S F A NaOH 2. S N to STP CaO or Na_2CO_3 3. S P N (concentrated only)	1. C: 10-100 #/# sol. matl. 2. Neutralize to pH 7 & route to STP. 3. Conc. solutions only/add lime or soda ash to pH 7 dispose solids properly neutralize any effluent	Can form HCl-if concentrated haul to manufacturer if possible.	19,28	0.25
Beryllium Chloride	no	 Backwash $Ca(OH)_2$ H_2SO_4 S P F N solids	Add lime to pH 8.5-9 let react 15 min. settle (filter if needed)/neutralize to pH 7 w/H_2SO_4.	Be sure to dilute the Cl to an acceptable discharge concentration	10,19	1.0 as Be 250 as Cl-
Beryllium Fluoride	no	 $Na_2CO_3/Ca(OH)_2$ HCl H_2O S P F N	Add $Ca(OH)_2$ to pH 8.5-9/settle/decant /add lime to pH 11/ let stand 24 hr/filter if necessary/neut. to pH 7 with HCl.	Must remove Be and F in subsequent processes.	26	1.0 as Be
Beryllium Nitrate	no	See Beryllium Chloride		Dilute system so nitrate discharge is acceptable.	19,26	1.0 as Be
Brucine	no	 Backwash S F A	C: 10-100 #/# sol. matl.		30*	45 as NO_3
Butyl Acetate	When diluted	 Backwash S F A Skim Solids	Gravity separation tests should be done C: 1-10 #/# sol. matl.	Skim off quickly to reduce load on carbon column.	10,19	35.5

TABLE 22. (continued)

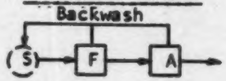
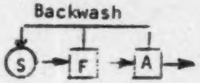
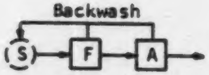
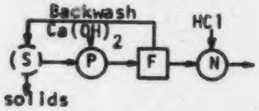
Hazardous Chemical	Amenable To Biological Trmt at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Butylamine	When diluted		C: 10-35 #/# sol. matl.	Send to STP if possible.	19,31	0.75
Butyric Acid	Can be discharged after neutralized		C: 10-35 #/# sol. matl.	No treatment per se given; dilution to below toxic level is necessary if no STP.	28*	
Cadmium Acetate	no	1.  2. 	1. Add lime to pH 10/mix/flocculate & settle/add HCl to pH 7 2. C: 10-100 #/# sol. matl.	Cadmium cannot be removed if CN^- is present/prior CN^- removal is required/ Iron addition may increase Cd removal/ dilute acetate if necessary.	19,20,24	0.01 as Cd
Cadmium Bromide	no	See Cadmium acetate		Dilute bromide to acceptable level.	19,20,24	0.01 as Cd
Cadmium Chloride	no	See Cadmium acetate		The precipitation reaction is recommended for removal at low concentrations. However, C adsorption is also effective/ dilute Cl^- to <250 mg/l if needed.	19,32	0.01 as Cd 250 as Cl

TABLE 22. (continued)

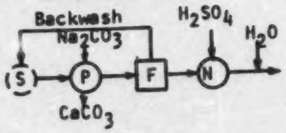
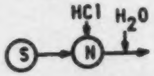
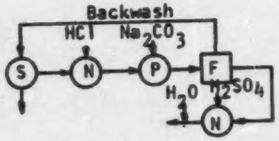
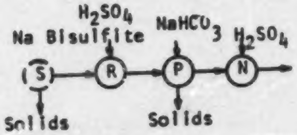
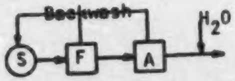
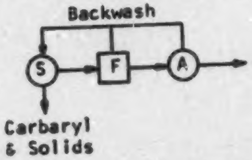
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Calcium Carbide	no	 Backwash Na_2CO_3 H_2SO_4 H_2O S P F N $CaCO_3$	Add sodium bicarbonate to pH 9; allow to settle; neutralize to pH 7; dilute to reduce C_2H_2 concentration	Take car to avoid explosion from vapors (C_2H_2); discharge when conc. is acceptable	10,19	0.125
Calcium Hydroxide	after neutralization	1.  2.  Backwash HCl Na_2CO_3 S N P F H_2O H_2SO_4 N	1. Settle and neut. HCl; dilute; discharge 2. To remove calcium: add HCl to pH 7; then add Na_2CO_3 to pH 9; settle; filter; neut. with H_2SO_4	Dilute ultil CaCl by prod. conc. is at acceptable levels; Use 2. if Ca must be removed	10,19	0.25
Calcium Hypochlorite	no	 H_2SO_4 Na Bisulfite $NaHCO_3$ H_2SO_4 S R P N Solids Solids	Add acid to pH 3; then bisulfite until no chlorine residual; after 15 min. add $NaHCO_3$ to ppt calcium carbonate pH 9; neutralize; discharge	Other reducing agents: sodium thiosulfate, ferrous salt, etc. can he used	19,28	0.125
Calcium Oxide	when neutralized	See Calcium Hydroxide	Add acid to pH 7; then add Na_2CO_3 to pH 9; ppt $CaCO_3$; neutralize to pH 7	Possible dilution after reaction to form calcium chloride; should check w/local authorities	28	0.25
Captan	no	 Backwash H_2O S F A	C: 100-300 #/# sol. matl.	--	30	--
Carbaryl (Sevin)	After reduction w/calcium hypochlorite for 24 hours	 Backwash S F A Carbaryl & Solids	C: 100-300 #/# sol. matl. Carbaryl will be removed during sedimentation	A large amount will sink to bottom of water body so dredging may be required	10,19	--

TABLE 22. (continued)

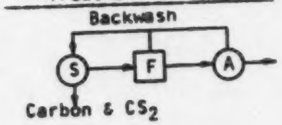
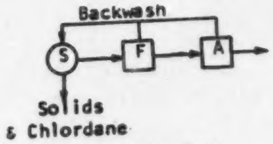
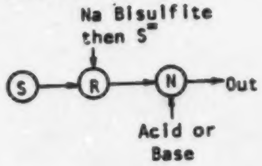
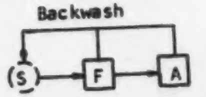
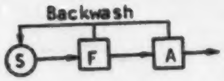
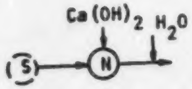
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STR	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Carbon Disulfide	no	 Backwash S F A Carbon & CS$_2$	C: 10-100 #/# sol. matl.	Dredging of the bottom of the water body may be needed	19,33	1.0
Chlordane	no	 Backwash S F A Solids & Chlordane	C: 100-300 #/# sol. matl.	Dredging of the bottom may be necessary	19	0.025
Chlorine	When reduced and diluted	 Na Bisulfite then S$^=$ S R N Out Acid or Base	Add H_2SO_4 to pH 2-3; add Na bisulfite until small or no chlorine residual; neutralize to pH 7	Carbon can be used for low concentration of Cl_2	19,34	0.15
Chloro-benzene	when diluted	 Backwash S F A	C: 10-100 #/# sol. matl.	--	19,33	17.5
Chloroform	when diluted	 Backwash S F A	C: 10-100 #/# sol. matl.	Sedimentation & dredging of water bottom may be necessary	10,19	6.0
Chlorosul-fonic acid	when neutralized	 Ca(OH)$_2$ H$_2$O S N	Add $Ca(OH)_2$ slowly to pH 7; dilute if necessary	Dissociates to H_2SO_4 & HCl in water and is explosive; dilute to meet Cl^- and $SO_4^=$ discharge levels	19	0.05 or 250 as SO_4 Cl

TABLE 22. (continued)

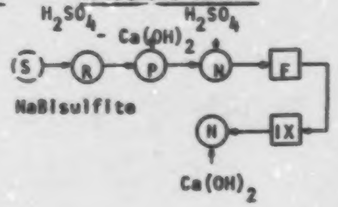
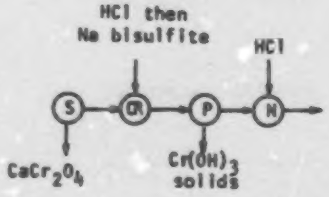
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Ammonium Bichromate	no	 H_2SO_4 Ca(OH)$_2$ H_2SO_4 S R P N F IX N NaBisulfite Ca(OH)$_2$	Add H_2SO_4 to pH 2-3/ add bisulfite to large ORP change or yellow to green color react 10 min/add Ca(OH)$_2$ to pH 8.5 settle/neutralize to pH 7/filter/IX in weekly acidic resin/ neutralize with lime to pH 7	Both chrome and ammonia must be removed/alum or polyelectrolyte may be necessary to aid settling of Cr(OH)$_3$	19	0.05 as Cr 0.01 as NH_3
Ammonium Chromate	no	See Ammonium Bichromate			19	0.05 as Cr 0.01 as NH_3
Calcium Chromate	no	 HCl then Na bisulfite HCl S CR P N $CaCr_2O_4$ Cr(OH)$_3$ solids	Adjust pH to 2-3; add bisulfite until color changes to green or a large color change; add lime to pH 8-9/ allow to settle/ neutralize	Alum or polymer may be required to improve the settling/ filtration after precipitation may allow removal of fines & suspended Cr(OH)$_3$	10,19, 20,24, 13,23	0.05 as Cr

TABLE 22. (continued)

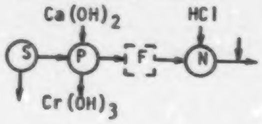
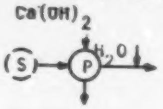
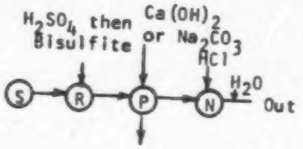
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Chromic Acetate	no		Adjust pH to 8-9 with slaked lime/allow to settle/filter if needed/neutralize	Alum or polyelectrolyte may be required to improve the settling/filtration after precipitation may allow removal of fines & suspended $Cr(OH)_3$	19,20	0.05 as Cr
Chromic Acid	no	See Chromic Acetate	--	--	19,20	0.05 as Cr
Chromic Sulfate	no	See Chromic Acetate			19,20	0.05 as Cr
Chromous Chloride	no		Add $Ca(OH)_2$ to pH 8.5/settle	Chromous will oxidize to chromic so sludge will be mixture of chromous & chromic hydroxide/use alum or polyelectrolyte to aid settling	19	0.05 as Cr
Chromyl Chloride	no	 H_2SO_4 then Bisulfite $Ca(OH)_2$ or Na_2CO_3 HCl H_2O Out S R P N	Add H_2SO_4 to pH 2-3; add bisulfite to large ORP change or color yellow to green; react 10 min/add lime/soda ash to pH 8-9/settle/add HCl to pH 7	Dilution may be necessary to reduce CL^- concentration	19,20	0.05 as Cr 250 as Cl

TABLE 22. (continued)

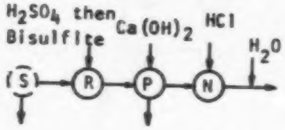
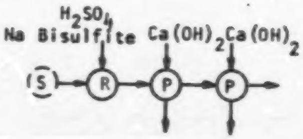
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	P.ov. Limit mg/l
Lithium Bichromate	no	 H_2SO_4 then Bisulfite $Ca(OH)_2$ HCl H_2O S R P N	Add H_2SO_4 to pH 2-3; add bisulfite to large ORP change or color yellow to green/react 10 mins/ add $Ca(OH)_2$ to pH 8-9/ settle neutralize with HCl to pH 7	Check acceptable lithium levels	19,24	0.05 as Cr
Lithium Chromate	no	See Lithium Bichromate		Check acceptable lithium levels	19,24	0.05 as Cr
Potassium Bichromate	no	See Chromyl Chloride			19,24	0.05 as Cr
Potassium Chromate	no	See Calcium Chromate			19,24	0.05 as Cr
Sodium Bichromate	no	See Calcium Chromate			19,24	0.05 as Cr
Sodium Chromate	no	See Chromyl Chlorate			19,24	0.05 as Cr
Strontium Chromate	no	 H_2SO_4 Na Bisulfite $Ca(OH)_2$ $Ca(OH)_2$ S R P P	Add H_2SO_4 to pH 2-3 add bisulfite until turns green or large ORP change/ add $Ca(OH)_2$ to pH 8.5/settle/add more lime to pH 10/ settle/discharge	Remove chromate sludge or decant supernatant before second lime addition check acceptable strontium levels	19,24,26	0.05 as Cr

TABLE 22. (continued)

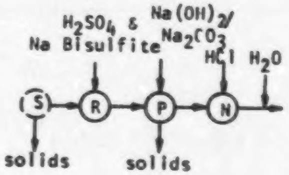
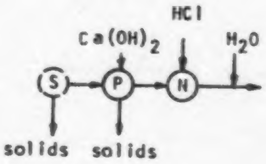
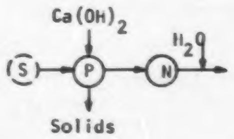
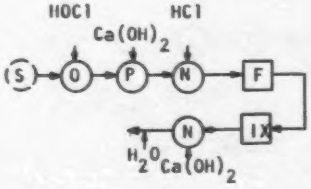
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Zinc Bichromate	no	 H_2SO_4 & Na Bisulfite Na(OH)$_2$/ Na_2CO_3 HCl H_2O S R P N solids solids	Add H_2SO_4 to pH 2-3/ add bisulfite until color turns green or large ORP change/ add 50/50 lime/soda ash to pH 7.5-8.5 settle $Zn(OH)_2$ and chrome sludge	Alum may aid in settling floc	10,19,20	0.05 as Cr
Cobaltous Bromide	no	 $Ca(OH)_2$ HCl H_2O S P N solids solids	Add lime to pH 8-8.5/ settle/neutralize to pH 7 with HCl	Dilution may be needed to meet the bromide discharge requirements/Both cobaltic & cobaltous hydroxide are insoluble at pH 8-8.5	19,26	0.05 as Co
Cobaltous Fluoride	no	 $Ca(OH)_2$ H_2O S P N Solids	Add lime to pH 8-8.5/ settle/allow to react 24 hours/neutralize and discharge	A long holding time is needed to reduce F^- concentration	19,33	0.05 as Co
Cobaltous Formate	no	See Cobaltous Bromide		Dilute to meet acceptable formate concentrations	19,26	0.05 as Co
Cobaltous Sulfamate	no	 HOCl $Ca(OH)_2$ HCl S O P N F IX N H_2O $Ca(OH)_2$	Add HOCl to residual then add $Ca(OH)_2$ to pH 8.5/settle $CaSO_4$ add HCl to pH 7/filter/ IX on weakly acidic resin/neutralize to pH 7	Sulfamate is converted to sulfuric acid and ammonia when oxidized	19,24,26	0.05 as Co

TABLE 22. (continued)

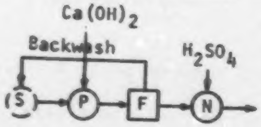
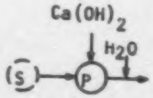
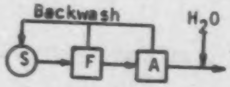
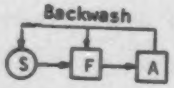
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Cupric Acetate	When dilute and neutralized		Add lime to pH 9.5 allow to settle/ filter for more solids removal/ neutralize to pH 7	Carbon may be beneficial in low ranges otherwise precipitation is effective/ ammonia must be removed prior to treatment	19,24,33	1.0 as Cu
Cupric Aceto-arsenite	no		Add $Ca(OH)_2$ to pH 8 and allow insoluble compound to precipitate	Dilute if necessary; initial material is insoluble in water so dredging may be necessary	19,24	0.05 as As
Cupric Chloride	When dilute and neutralized	See Cupric Acetate		Dilute to meet acceptable Cl- concen.	19,24,33	1.0 as Cu
Cupric Formate	When dilute and neutralized	See Cupric Acetate		Formate is degradeable in STP	19,24,33	1.0 as Cu
Cupric Glycinate	no		C: 10-100 #/# sol. material	Glycinate forms a complex which should be adsorbed/untested treatment scheme	19,24	1.0 as Cu
Cupric Lactate	When dilute and neutralized		C: 10-100 #/# sol. material	Lactate also complexes/untested treatment scheme	19,24,26	1.0 as Cu
Cupric Nitrate	When dilute and neutralized	Same as Cupric Acetate		Dilute nitrate to below acceptable discharge level	19,24,26	1.0 as Cu

TABLE 22. (continued)

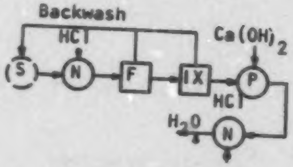
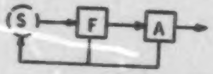
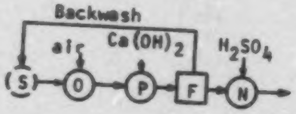
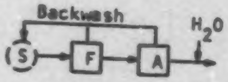
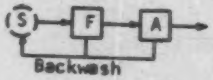
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Cupric Oxalate	When dilute and neutralized	See Cupric Glycinate		Forms complex/ untested treatment scheme	19,24,33	1.0 as Cu
Cupric Subacetate	When dilute and neutralized	See Copper Acetate			19,24,26	1.0 as Cu
Cupric Sulfate	When dilute and neutralized	See Copper Acetate			19,24,26	1.0 as Cu
Cupric Sulfate, Ammoniated	When dilute and neutralized		Add HCl to pH 7/ filter exchange/add $Ca(OH)_2$ to pH 9.5/ settle/neutralize/ dilute	Decomposes to NH_4^+ and $CuSO_4$	19,24,26	1.0 as Cu
Cupric Tartrate	When dilute and neutralized		C: 10-100 #/# sol. material	Forms complex/untested treatment scheme	28	1.0 as Cu
Cuprous Bromide	no		Add air 70% of max. residual/add lime to pH 9.5/filter neutralize to pH 7	Coagulant may be needed to increase settling rate	30	1.0 as Cu
Coumaphos	When diluted		C: 100-300 #/# sol. material			
Cresol	When diluted		C: 1-10 #/# sol. material		10,19	0.001

TABLE 22. (continued)

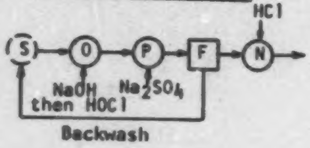
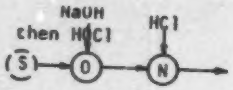
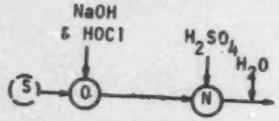
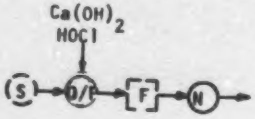
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Barium Cyanide	When acclimated (cyanate only)	 S O P F N HCl NaOH then HOCl Na_2SO_4 Backwash	Add NaOH to pH 8.5 and then HOCl to a residual/react 1 hr/ add Na_2SO_4 excess SO_4/settle/ filter/and neutralize to pH 7	Coagulant may be needed to increase settling rate use sulfate test to establish dosage for Na_2SO_4/shorter reaction-ca 10 min at pH of 10-11 will create cyanates (much less toxic)	19,20	0.01 as CN
Calcium Cyanide	If acclimated		Add NaOH to pH 8.5 then add HOCl to 10% excess/react 1 hr/ neutralize to pH 7	A shorter reaction time at pH of 10-11 dosage will allow reduction to cyanate for discharge to STP	10,19,20	0.01 as CN
Hydrogen Cyanide (Hydrocyanic Acid)	If acclimated		Add NaOH to pH 8-8.5 then add HOCl to a residual/add 10% XS HOCl/react 1 hr/neutralize w/H_2SO_4 prior to discharge	Do not allow pH to drop below neutral or NH_4 will be formed /add large excess HOCl to avoid the liberation of toxic cyanogen chloride	10,19,20	0.01 as CN
Potassium Cyanide	If acclimated	See Calcium Cyanide			10,19,20	0.01 as CN
Sodium Cyanide	If acclimated	See Calcium Cyanide			10,19,20	0.01 as CN
Zinc Cyanide	no		Add lime to pH 8.5and then add excess HOCl allow to react 1 hr/ settle/filter if nec. neutralize	The CN must be removed prior to zinc treatment/ also keep pH up until CN^- is removed to prevent HCN generation/filtration at end may help effluent quality	10,19,20 *	0.01 as CN

TABLE 22. (continued)

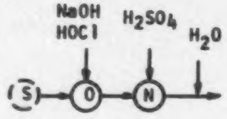
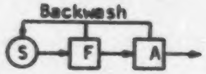
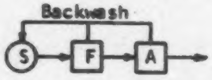
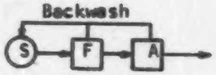
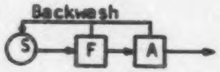
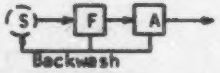
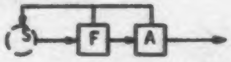
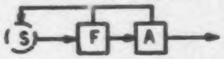
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Cyanogen Chloride	if acclimated	 NaOH HOCl H_2SO_4 H_2O S O N	Add NaOH to pH 8-8.5 & 10% excess HOCl/allow to react 1 hr/neutralize/dilute if necessary	Activated carbon may also be used if necessary	10,19, 20	0.01 as CN
Cyclohexane	When diluted	 Backwash S F A	C: 10-100 #/# sol. matl.	Skim cyclohexane off surface and then adsorb remainder on carbon	10,19	52.5
2,4-D (acid)	no	 Backwash S F A	C: 35-100 #/# sol. matl.	Dissolves slowly so dredge from bottom	10,19	0.5
2,4-D (ester)	no	 Backwash S F A	C: 35-100 #/# sol. matl.	Dissolves slowly so dredge from the bottom	10,19	0.5
Dalapon	no	 Backwash S F A	C: 100-300 #/# sol. matl.		19	
DDT	no	 S F A Backwash	C: 100-300 #/# sol. matl.		10,19	0.05
Diazinon	no		C: 100-300 #/# sol. matl.	Dredge if possible then adsorb soluble portion on carbon	30	
Dicamba	no		C: 35-100 #/# sol. matl.		30	

TABLE 22. (continued)

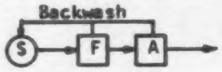
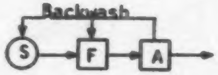
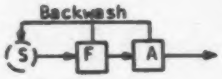
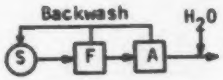
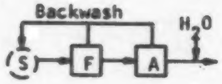
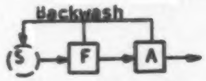
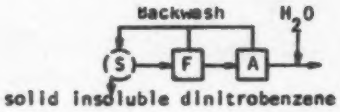
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Dichlobenil	no	 Backwash S F A	C: 100-300 #/# sol. matl.	May not dissolve so dredging or skimming may be required	30	
Dichlone	no	 Backwash S F A	C: 100-300 #/# sol. matl.		30	
Dichlorvox	no	 Backwash S F A	C: 100-300 #/# sol. matl.		30	
Dieldrin	no	 Backwash H_2O S F A	C: 100-300 #/# sol. matl.	Will sink so dredging of bottom is necessary with carbon adsorption of effluent-dilution may be required prior to discharge	10,19	0.012
Diethylamine	When diluted	 Backwash H_2O S F A	C: 10-100 #/# sol. matl.	Also be neutralized w/acid or use cation exchange	10,19	3.75
Dimethylamine	When diluted	 Backwash S F A	C: 10-100 #/# sol. matl.	Can be neutralized w/acid or use cation exchange	10,19	0.90
Dinitrobenzene	no	 Backwash H_2O S F A solid insoluble dinitrobenzene	C: 10-35 #/# sol. matl.	Dredge bottom of water body also to remove insoluble material	10,19	0.05

TABLE 22. (continued)

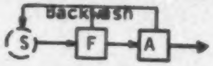
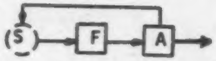
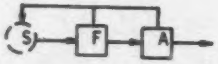
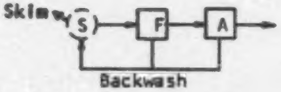
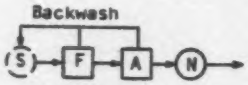
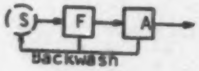
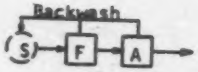
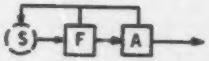
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Dinitrophenol	no		C: 10-35 #/# sol. matl.		19,30	0.010
Diquat	no		C: 100-300 #/# sol. matl.		19,30	
Disulfoton	no		C: 100-300 #/# sol. matl.		30	
Diuron	no		C: 100-300 #/# sol. matl.	Very little will dissolve unless a wetting agent is available so skimming or dredging may be necessary	10,30	
Dodecylbenzene-sulfonic acid	When diluted		Neutralization may be needed C: 10-35 #/# sol. matl.		23	
Dodecylbenzene-sulfonic acid, calcium salt	When diluted		C: 10-35 #/# sol. matl.	Dilute if needed or remove Ca separately	23	
Dodecylbenzene-sulfonic acid isopropanolamine salts	When diluted		C: 10-35 #/# sol. matl.		23	
Dodecylbenzene-sulfonic acid sodium salt	When diluted		C: 10-35 #/# sol. matl.		23	

TABLE 22. (continued)

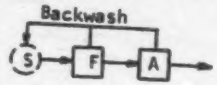
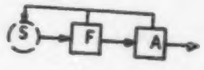
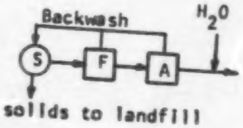
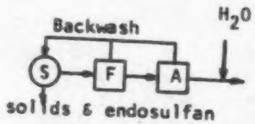
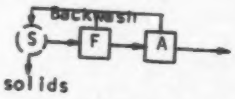
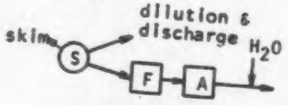
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Dodecylbenzene-sulfonic acid, triethanolamine salt	When diluted	 Backwash S F A	C: 10-35 #/# sol. matl.		23	
Dursban	no		C: 100-300 #/# sol. matl.		30	
Endrin	no	 Backwash H_2O S F A solids to landfill	C: 100-300 #/# sol. matl.	Dilution may be required prior to discharge-check to determine if skimming or dredging is needed.	10,19	0.005
Endosulfan	no	 Backwash H_2O S F A solids & endosulfan	C: 100-300 #/# sol. matl.	sinks--so dredging may be needed--also dilute treated effluent if required.	10	
Ethion	no	 Backwash S F A solids	C: 100-300 #/# sol. matl.		30	
Ethylbenzene	When dilute	 skim dilution & discharge H_2O S F A	C: 10-100 #/# sol. matl.	Skimming may be sufficient, however carbon will provide further polishing.	12,19	22

TABLE 22. (continued)

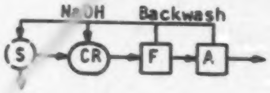
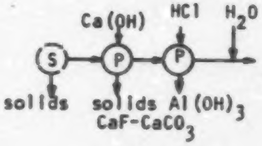
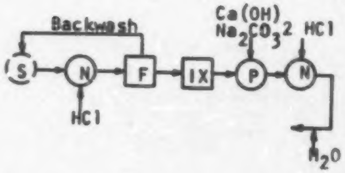
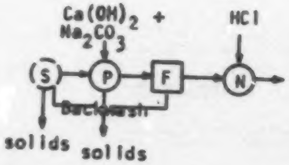
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Ethylene Diamine	When dilute	 NaOH Backwash S CR F A	C: 35-100 #/# sol. matl. Add NaOH to make alkaline (pH 8-8.5). before adsorption		10	1.27
Aluminum Fluoride	--	 Ca(OH) HCl H_2O S P P solids solids $Al(OH)_3$ $CaF-CaCO_3$	Add lime to pH 11 let stand overnight (24 hrs) then add HCl to pH 7 settle to remove Al $(OH)_3$ discharge.	Complete fluoride removal requires 24 hours/add coagulant to aid settling of $Al(OH)_3$	10,19	0.6-1.7 as F
Ammonium Bifluoride	When neutralized and diluted	 Backwash Ca(OH) $Na_2CO_3$2 HCl S N F IX P N HCl H_2O	Add HCl to pH 7/ filter/ion exchange add 50/50 $Ca(OH)_2/Na_2CO_3$ to pH 11/react 24 hrs/ decant/neutralize to pH 7.	Fluoride requires 24 hrs. for ppt as $CaF-CaCO_3$	19,28	0.6-1.7 as F
Ammonium Fluoride	When neutralized and diluted	See Ammonium Bifluoride			10,19	0.6-1.7 as F
Hydrofluoric Acid	If diluted	 $Ca(OH)_2$ + Na_2CO_3 HCl S P F N Backwash solids solids	Add 50/50 mixture of soda ash/lime until pH 11; allow to stand overnight/ filter/neutralize with HCl.	Fluoride requires 24 hrs. for ppt as $CaF-CaCO_3$	19,28	0.01

TABLE 22. (continued)

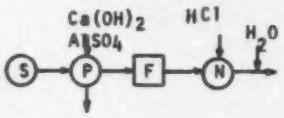
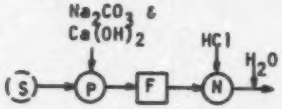
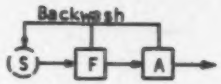
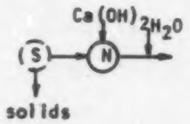
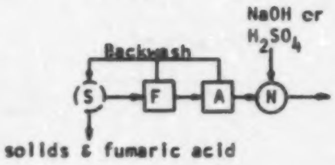
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Sodium Bifluoride	If diluted	 Ca(OH)2 AlSO4 HCl H2O S P F N	Lime to pH 11/add alum to a good floc; allow to react for 24 hrs/filter/neutralize & dilute.	Fluoride requires 24 hr reaction time	19,28	0.6-1.7 as F
Sodium Fluoride	If diluted	Same as Sodium Bifluoride			19,28	0.6-1.7 as F
Stannus Fluoride	If diluted	 Na2CO3 & Ca(OH)2 HCl H2O S P F N	Add 50/50 mixture of lime and soda ash to pH 11/allow to stand 24 hrs/filter/neutralize and dilute.	Alum may be used to improve the settling rate.	19,28	0.6-1.7 as F
Formaldehyde	When dilute	 Backwash S F A	C: 35-100 #/# sol. matl.		31	0.15
Formic Acid	When dilute	 Ca(OH)2 2H2O S N solids	Add lime to pH 7.	Sodium bicarbonate can also be used.	31	0.45
Fumaric Acid	When dilute	 NaOH or H2SO4 Backwash S F A N solids & fumaric acid	C: 35-100 #/# sol. matl. Neutralize if necessary	Remove fumaric acid w/solids-bottom of water body may require dredging; Anion exchangers may also be used.	31	

TABLE 22. (continued)

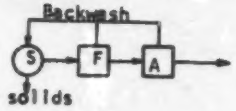
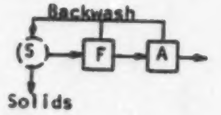
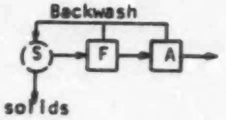
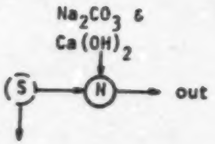
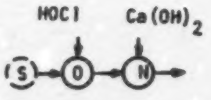
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Furfural	When dilute		C: 10-100 #/# sol. matl.	Dredge, pump or vacuum the undissolved portion from bottom.	10,19,20	1.0
Guthion	When dilute		C: 100-300 #/# sol. matl.	Dredge pump or vacuum undissolved portion from bottom-hydrolyzes in acid or cold alkali	10,19	0.01
Heptachlor	no		C: 100-300 #/# sol. matl.	Vacuum or pump undissolved portion from bottom/remove heptachlor w/solids; very little dissolves.	10,19,37	0.025
Hydrochloric Acid	When neutralized		Add 50/50 lime soda ash to pH 7	Stirring is needed; do not add NaOH because resulting reaction is quite violent/check to meet acceptable Cl^- levels	10,19	0.35 250 mg/P as Cl-
Hydroxylamine	When dilute		Oxidize by slowly adding weak HOCl/neutralize by adding $Ca(OH)_2$ to pH 7	Add only dilute HOCl to prevent violent reaction/forms HNO_3 to be neutralized	10	0. 5 as HNO_3

TABLE 22. (continued)

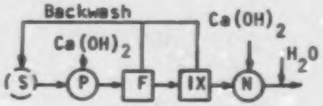
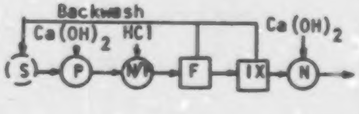
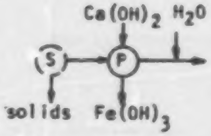
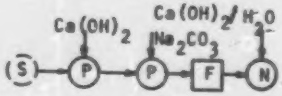
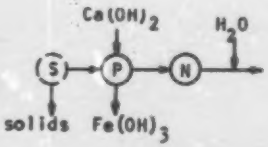
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Ferric Ammonium Citrate	When neutralized and dilute	 Backwash $Ca(OH)_2$ $Ca(OH)_2$ H_2O S P F IX N	Add $Ca(OH)_2$ to pH 6-7/ppt Fe/filter/exchange neutralize to pH 7	Dilute may be needed for citrate	19*	0.03 as Fe
Ferric Ammonium Oxalate	When neutralized and dilute	 Backwash $Ca(OH)_2$ HCl $Ca(OH)_2$ S P W F IX N	Add $Ca(OH)_2$ to pH 9/settle/reduce pH 6-7 w/HCl/ppt Fe/filter exchange/neutr to pH 7	The first ppt should remove oxalate	19*	0.03 as Fe
Ferric Chloride	When dilute	 $Ca(OH)_2$ H_2O S P solids $Fe(OH)_3$	Add lime to about pH 7 and ppt $Fe(OH_3)$ neutralize if necessary	Ferric hydroxide is least soluble at pH 7 so this pH is recommended	10,19	0.03 as Fe
Ferric Fluoride	When dilute	 $Ca(OH)_2$ $Ca(OH)_2$/Na_2CO_3 H_2O S P P F N	Add lime to pH 7/allow $Fe(OH)_3$ to settle/add more lime/soda ash to pH 11/settle 24 hrs/filter/neutralize	Alum may improve settling after second lime addition/Fluoride require 24 hrs for removal	19,20,28	0.05 as Fe
Ferric Nitrate	When dilute	 $Ca(OH)_2$ H_2O S P N solids $Fe(OH)_3$	Add lime to pH 7 and ppt $Fe(OH)_3$/neutralize to pH 7 with HCl or lime if necessary	Dilute nitrate to acceptable level	10,19	0.03 as Fe
Ferric Sulfate	When dilute	See Ferric Chloride			10,19,24	0.03 as Fe

TABLE 22. (continued)

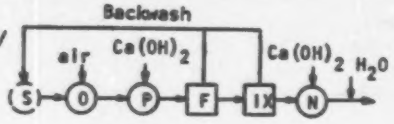
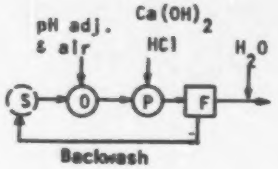
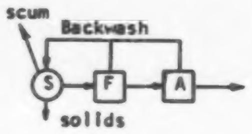
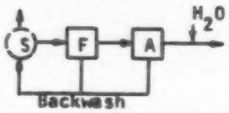
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Ferrous Ammonium Sulfate	When oxidized/ neutralized/ diluted	 Backwash air $Ca(OH)_2$ $Ca(OH)_2$ H_2O S O P F IX N	Aerate until no Fe^{+2} remained/add $Ca(OH)_2$ to pH 6-7/ settle/filter/ exchange/neutralize to pH 7	Oxidation changes ferrous to ferric/ should occur rapidly	19,24*	0.03 as Fe
Ferrous Chloride	When dilute	 pH adj. & air $Ca(OH)_2$ HCl H_2O S O P F Backwash	Adjust pH to 7.5 with lime or acid/ allow to aerate until no ferrous iron exists/ add lime and adjust pH to 7/react/settle/ filter/discharge	The lime should be added to achieve sufficient flocculation/polyelectrolyte may be needed	10,19,20	0.03 as Fe
Ferrous Sulfate	When dilute	See Ferrous Chloride		The sulfate ion may result in large amounts of calcium sulfate in the sludge	10,19,20	0.03 as Fe
Isoprene	When dilute	 scum Backwash S F A solids	C: 10-100 #/# sol. matl.	Skim undissolved off top with booms and adsorbent	10,19	110
Kelthane	When dilute	 H_2O S F A Backwash	C: 100-300 #/# sol. matl.	Dilution may be required prior to discharge, check bottom to see if dredging is required	10,30	

TABLE 22. (continued)

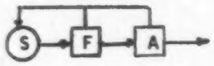
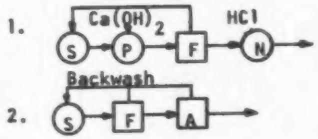
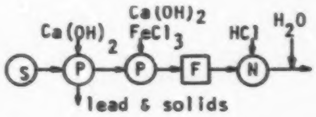
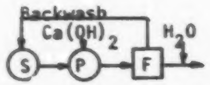
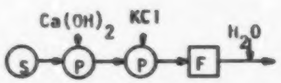
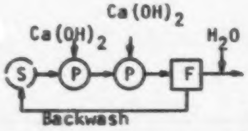
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Refence	Prov. Limit mg/l
Kepone	no		C: 100-300 #/# sol. matl.	Kepone is extremely toxic, dilution may be needed prior to discharge	-	-
Lead Acetate	no	 1. Ca(OH)2 HCl S P F N Backwash 2. S F A	1. Add $Ca(OH)_2$ to pH 8-9/ppt filter/ neutralize to pH 7 if needed 2. C 10-100 #/# sol. matl.	Use Carbon as a polishing step/ Na_2CO_3 may also be used	19,20*	0.05 as Pb
Lead Arsenate	no	 Ca(OH)2 Ca(OH)2 FeCl3 HCl H2O S P P F N lead & solids	Add $Ca(OH)_2$ to pH 8.5/settle/add more $Ca(OH)_2$ to pH 10.5 and $FeCl_3$ to form floc/settle/filter/ neutralize if needed	Vacuum, dredge or pump off bottom. Both Arsenic & lead will be removed	10,19,20 *	0.05 as Pb 0.05 as As
Lead Chloride	no	 Backwash Ca(OH)2 H2O S P F	Add $Ca(OH)_2$ to pH 8,5/ppt lead filter/ discharge. Use carbon as a polishing step	Dredge, vacuum or pump undissolved portion from bottom	10,19,20 *	0.05 as Pb
Lead Fluoraborate	no	 Ca(OH)2 KCl H2O S P P F	Add $Ca(OH)_2$ to pH 8.5 ppt/decant/add KCl to ppt/filter/discharge	Can precipitate some fluoraborate with KCl untested scheme	19,24*	0.05 as Pb
Lead Fluoride	no	 Ca(OH)2 Ca(OH)2 H2O S P P F Backwash	Add $Ca(OH)_2$ to pH 8.5/allow to settle/ decant & add lime to pH 11/settle 24 hrs/ filter/discharge	Dredge, vacuum or pump undissolved portion from the bottom. Fluoride requires 24 hrs to remove	19,20,28	0.05 as Pb

TABLE 22. (continued)

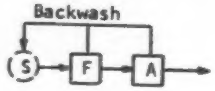
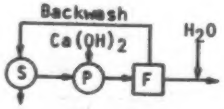
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Lead Iodide	no	See Lead Chloride			10,19,28	0.05 as Pb
Lead Nitrate	no	See Lead Chloride		Dilute so nitrate conc. reaches acceptable levels/dredge, pump, etc. undissolved portion from bottom	10,19,28	0.05 as Pb
Lead Stearate	no	See Lead Chloride			10,19,28	0.05 as Pb
Lead Sulfate	no	See Lead Chloride		Pump vacuum or dredge undissolved portion and solids from bottom	10,19,28	0.05 as Pb
Lead Tetraacetate	no		C: 10-100 #/# sol. mtl.	Dredge undissolved portion from bottom	31	0.05 as Pb
Lead Thiocyanate	no	See Lead Chloride		Dilute cyanate if needed	10,19,20	0.05 as Pb
Lead Thiosulfate	no	See Lead Chloride			10,19,20	0.05 as Pb
Lead Tungstate	no		Add lime to pH 7-8/ filter to remove fines/settling is necessary	Dredge, pump or vacuum undissolved portion or solids from bottom	26 *	0.05 as Pb

TABLE 22. (continued)

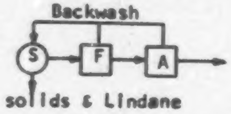
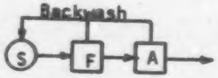
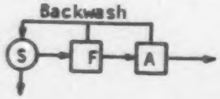
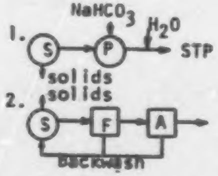
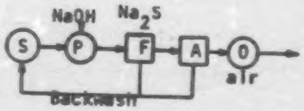
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Lindane	-	 Backwash S F A solids & Lindane	C: 100-300 #/# sol. mtl.	Dredge, pump or vacuum undissolved portion of solids from bottom	10	-
Malathion	-	 Backwash S F A	C: 100-300 #/# sol. matl.	Dredge, pump or vacuum undissolved portion from bottom	10	-
Maleic Acid	After neutralization	 Backwash S F A	C: 1-10 #/# sol. matl.	Dredge bottom as fast as possible	19*	0.05
Maleic Anhydride	After neutralization	 1. S P NaHCO3 H2O STP solids 2. solids S F A Backwash	1. Add $NaHCO_3$ to pH 7/ dilute; send to STP 2. C: 1-10 #/# sol. matl.	Either option is acceptable depending on available chemicals & discharge point	10,19	0.05
Mercuric Acetate	no	 S P NaOH Na2S F A O air Backwash	Raise pH to 7-8 with NaOH/add Na_2S to a $S^=$ residual/filter/ adsorb & aerate to 5 mg/l DO residual	Take care not to evolve H_2S at low pH	19,20,24	0.005 as Hg

TABLE 22. (continued)

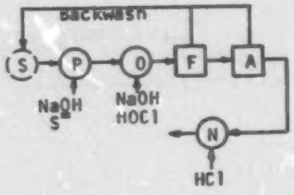
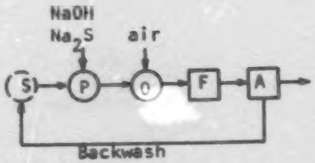
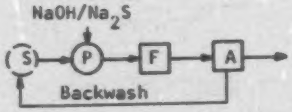
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Mercuric Cyanide	no	 Backwash S P O F A N NaOH S= NaOH HOCl HCl	Raise pH to 8 with NaOH/add H_2S to S residual/react 5 min/ settle, remove sludge/ adjust pH to 8.5 add HOCl to residual + 10% excess/react 1 hr./filter/adsorb/ neutralize. C: 1-10 #/# sol. matl.	CN- can be reacted to cyanates if pH is raised to 10-11/ reaction time is reduced to 10 min. Dilute cyanates if necessary.	19,20,24	0.005 as Hg
Mercuric Nitrate	no	See Mercuric Acetate			19,20,24	0.005 as Hg
Mercuric Sulfate	no	See Mercuric Acetate			19,20,24	0.005 as Hg
Mercuric Thiocyanate	no	See Mercuric Acetate (most will settle)		Sedimentation is required/can dilute if necessary	19,20,24	0.005 as Hg
Mercurous Nitrate	no	1. 	1. Add NaOH to pH 6-8/ add Na_2S to residual aerate to mercuric state/filter/adsorb. C; 1-10 #/# sol. matl.	If option 2 is used, mercury and mercuric sulfide will be present in sludge	19,24	0.005 as Hg
		2. 	2. Add NaOH to pH 7-8/ add Na_2S/let stand until no mercurous ion			

TABLE 22. (continued)

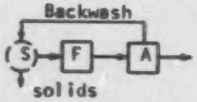
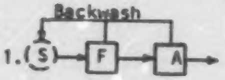
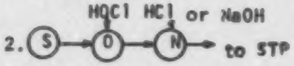
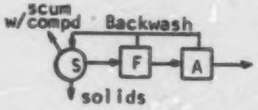
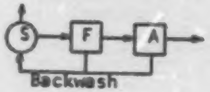
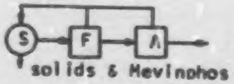
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Methoxychlor	no	 Backwash S F A solids	C: 100-300 #/# sol. matl.	Dredge, pump or vacuum undissolved portion from bottom	10	-
Methyl mercaptan	After chlorine reduction (treatment scheme #2)	1.  Backwash S F A	1. C: 35-100 #/# sol. matl.	Be sure to eliminate all ignition sources	10,19	-
		2.  HOCl HCl or NaOH S O N to STP	2. Add HOCl to Cl residual/then neutralize to pH 7 if necessary			
Methyl methacrylate	When dilute	 scum w/compd Backwash S F A solids	C: 10-35 #/# sol. matl.	Skim the slick off surface of material	10,19	20.5
Methyl Parathion	When dilute into effective activated sludge system	 S F A Backwash	C: 100-300 #/# sol. matl.	Vacuum, dredge or pump undissolved portion from bottom	10,19	0.001
Mevinphos (Phosdrin)	no	 S F A solids & Mevinphos	C: 100-300 #/# sol. matl.	Check bottom & remove any insoluble mat'l	n0	-

TABLE 22. (continued)

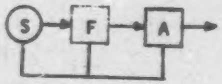
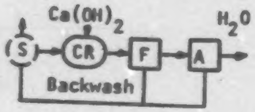
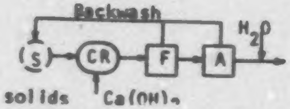
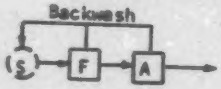
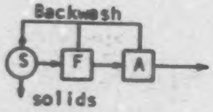
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Mirex	no		C: 100-300 #/# sol. mat'l	May require dilution prior to discharge	-	-
Monoethylamine	When dilute or reduced	 Ca(OH)$_2$ H$_2$O S CR F A Backwash		May be able to skim some compounds from surface. Cation exchange can be used on acid or neutral solutions may require dilution	10,19	0.9
Monomethylamine	When dilute	 Backwash H$_2$O S CR F A solids Ca(OH)$_2$	Raise pH to 8 with lime/filter. C: 10-100 #/# sol. matl.	May also be used for exchange	10,19	0.9
Naled	no	 Backwash S F A	C: 100-300 #/# sol. matl.		30	
Naphthalene	When dilute	 Backwash S F A solids	C: 10-35 #/# sol. matl.	Dredge, vacuum or pump undissolved portion & solids from bottom	10,19	2.5

TABLE 22. (continued)

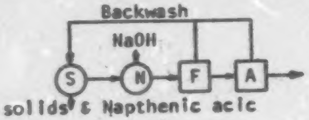
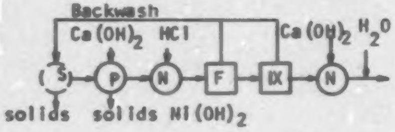
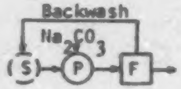
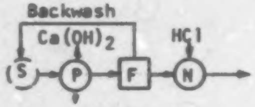
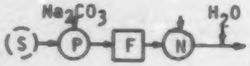
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Napthenic acid	When neutralized	 Backwash NaOH S N F A solids & Napthenic acic	Add NaOH to pH 7/ filter/adsorb on carbon. C: 10-35 #/# sol. matl.		19	-
Nickel Ammonium Sulfate	no	 Backwash Ca(OH)2 HCl Ca(OH)2 H2O S P N F IX N solids solids Ni(OH)2	Add $Ca(OH)_2$ to pH 10/ppt Ni/add HCl to pH 7/filter/ neutralize to pH 7	May require dilution to reach SO_4 discharge levels. Make sure ammonia not present in high amounts/lime treatment should result in lower nickel levels	19,24 *	0.05 as Ni
Nickel Chloride	no	1.  Backwash Na2CO3 S P F 2.  Backwash Ca(OH)2 HCl S P F N	1. Add Na_2CO_3 to pH 8-8.5/allow to settle/filter 2. Add lime to pH 10/allow to settle/ filter/neutralize		19,24 *	0.05 as Ni
Nickel Formate	no	 Na2CO3 H2O S P F N	Add soda ash to pH 8-8.5/allow to settle/ filter/neutralize to pH 7	Determine acceptable formate discharge level/ion exchange or carbon adsorption may be needed	19,24	0.05 as Ni

TABLE 22. (continued)

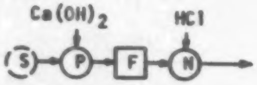
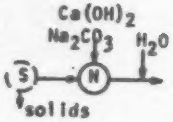
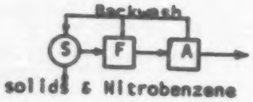
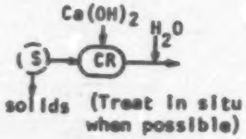
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Nickel Hydroxide	no	 Ca(OH)2 HCl S P F N	Add lime to pH 10/ allow to settle/ filter/neutralize with HCl	A coagulant may aid settling/neutralization with acid may be necessary first	19,20,24	0.05 as Ni
Nickel Nitrate	no	See Nickel Chloride			19,24	0.05 as Ni
Nickel Sulfate	no	See Nickel Chloride		Check discharge conc. for sulfates	19,24	0.05 as Ni
Nitric Acid	When neutralized	 Ca(OH)2 Na2CO3 H2O S N solids	Add 50/50 soda ash to slaked lime until pH 7/dilute/discharge	Dilution to reduce nitrate concentration	10,19	0.25
Nitrobenzene	Not to all systems/only some	 Backwash S F A solids & Nitrobenzene	C: 10-100 #/# sol. matl.	Dredge, pump or vacuum insoluble portion from bottom	10,19 *	0.25
Nitrogen Dioxide	After neutralization and dilution	 Ca(OH)2 H2O S CR solids (Treat in situ when possible)	Add $Ca(OH)_2$ to pH 7-8 dilute with water	Beware of flash fire Self-contained breathing apparatus mandatory/ lime addition forms nitrates and nitrates reqr. dilution	28 *	-

TABLE 22. (continued)

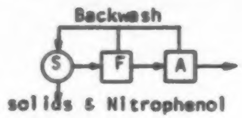
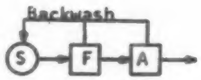
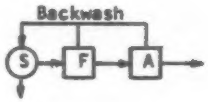
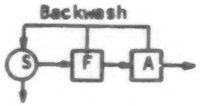
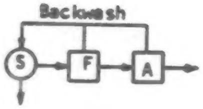
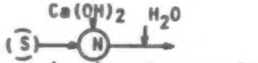
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Nitrophenol	no	 Backwash S F A solids & Nitrophenol	C: 10-35 #/# sol. matl.	Dredge, pump or vacuum insoluble portion from bottom	18,19	0.01
Para-formaldehyde	When dilute	 Backwash S F A	C: 10-35 #/# sol. matl.		10,19	0.15
Parathion	When dilute if activated sludge process is acclimated	 Backwash S F A	C: 100-300 #/# sol. matl.	Dredge, pump or vacuum undissolved portion from bottom	10,19	0.005
Pentachloro-phenol	no	 Backwash S F A	C: 100-300 #/# sol. matl.	Dredge, pump or vacuum undissolved portion from bottom/ ion exchange may be used if available	10,19	0.25
Phenol	No unless very dilute	 Backwash S F A	C: 1-10 #/# sol. matl.	Dredge undissolved portion from bottom	10,19	0.001
Phosgene	no	 Ca(OH)2 H2O S N (Treat in situ when possible)	Add $Ca(OH)_2$ to pH 7-8/ dilute with H_2O	Extreme caution needed/use self-contained breathing apparatus/toxic gas	*	0.02

TABLE 22. (continued)

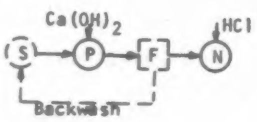
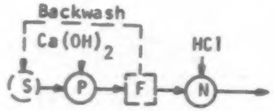
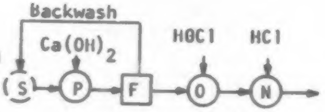
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Specifications	Comments	Reference	Prov. Limit mg/l
Phosphoric Acid	When neutralized		Add lime to pH 11/ allow to settle (an anionic polymer may help)/filter if needed/ neutralize to pH 7	The volume of sludge may be excessive so evaluation of this aspect from bench tests is required/ use $CaCl_2$ to reduce volume and air removal		—
Phosphorus	no	Place under water or wet sand and remove from scene to manufacturer		Will sink but caution must be taken to avoid contact with air or risk spontaneous ignition		0.005
Phosphorus Oxychloride	If neutralized & diluted		Add lime to pH 11/ (check to see if $CaCl_2$ removes more P)/settle/ (use anionic polymer if needed)/filter if necessary/neutralize to pH 7 with HCl	This compound decomposes to HCl and phosphoric acid/ large volumes of sludges may be produced so this factor must be considered-- use $CaCl_2$ with $Ca(OH)_2$ to reduce sludge volume and remove P	10,20, 32	0.35
Phosphorus Pentasulfide	If neutralized & diluted	 Backwash $Ca(OH)_2$ HOCl HCl S P F O N	Add lime to pH 11/ settle/filter if necessary/oxidize with HOCl until residual exists/neutralize with HCl	Decomposes to form H_2S and phosphoric acid so immediately raise the pH to avoid evolution of toxic H_2S	30 *	0.05
Phosphorus Trichloride	If neutralized & diluted	See Phosphorus Oxychloride				

TABLE 22. (continued)

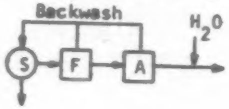
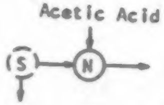
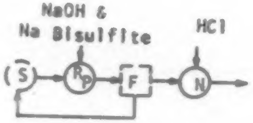
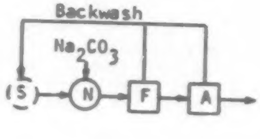
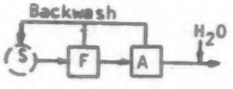
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Specifications	Comments	Reference	Prov. Limit mg/l
Polychlorinated Biphenyls	no		C : 100-300 #/# sol. matl.	Dredge, vacuum or pump undissolved portion and solids from bottom	10	0.025 to 0.05
Potassium Hydroxide	When neutralized and diluted		Add acetic acid to pH 7	Cation exchange may also be used. Care must be taken to avoid excessive heat buildup	10,19	0.10
Potassium Permanganate	When reduced & diluted		Adjust pH to 9-10 with NaOH and add bisulfite to large ORP change/ react 10 min/flocculate & settle/filter if needed/neutralize to pH 7	Natural reducing agent will most likely reduce the permanganate/ carbon may be used as reducer also	19,22	0.05 as Mn
Propionic acid	when dilute & neutralized		Add Na_2CO_3 to pH 7/ filter/adsorb C: 10-100 #/# sol. matl.	Not a problem in sea water because ppt with $CaCl_2$	10,19	1.25
Propionic Anhydride	When dilute & neutralized	See Propionic Acid	C: 10-100 #/# sol. matl.	Will not dissolve in salt water	10	1.25
Propyl Alcohol	When dilute		C: 10-100 #/# sol. matl.	Carbon may be ineffective so extensive dilution may be required	10,19	25

TABLE 22. (continued)

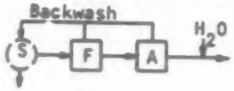
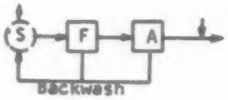
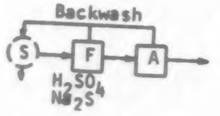
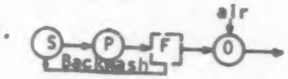
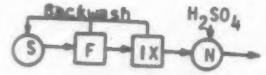
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Pyrethrins	no	 Backwash S F A H2O	C: 100-300 #/# sol. matl.		10,30	-
Quinoline	no	 S F A Backwash	C: 10-35 #/# sol. matl.	Pump or vacuum undissolved portion from bottom/ will only dissolve slowly	10,30	-
Resorcinol	no	 Backwash S F A H2SO4 Na2S	C: 1-10 #/# sol. matl.	Is very soluble so all water should be treated	10,30	-
Selenium Oxide	no	1.  S P F O air Backwash 2.  Backwash S F IX N H2SO4	1. Add acid to pH 6.5, add Na_2S until slight excess settle/ filter if needed/ oxidize to remove S 2. Filter/exchange for Se removal/neutralize	Take care to avoid evolution of H_2S/ Use ion exchange if media is available or if desired	19,20,24 *	0.01 as Se
Sodium Selenite	no	See Selenium oxide			19,20,24 *	0.01 as Se

TABLE 22. (continued)

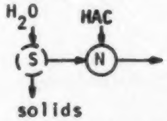
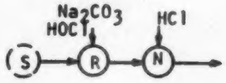
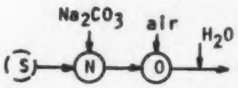
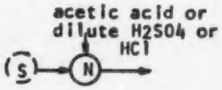
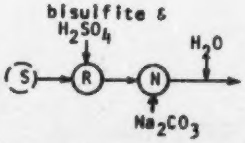
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Sodium	When neutralized	1.  H_2O HAC S N solids 2. If on land, cover with oil and haul. Protect from contact with water or air.	Add acetic acid to pH 7/dredge	Dilute prior to neutralization/ is dissolved in water as NaOH	10,19	0.1 as NaOH
Sodium Bisulfite	After reduced with hypochlorite	 Na_2CO_3 HOCl HCl S R N	Add soda ash to pH 10/ then add HOCl to a chlorine residual/ react 2 hrs/neutralize with HCl and discharge	Be sure chlorine residual is low	10,19,28	
Sodium Hydrosulfide	When reduced	 Na_2CO_3 air H_2O S N O	Add Na_2CO_3 to pH 7-- air to 70% max. DO level	Remove any solids to land fill	10,19	
Sodium Hydroxide	When neutralized	 acetic acid or dilute H2SO4 or HCl S N	Add acid to pH 7/ discharge	Be careful not to create strong reaction	10,19,28	0.1 as NaOH
Sodium Hypochlorite	After reduction & neutralization	 bisulfite & H_2SO_4 H_2O S R N Na_2CO_3	Add bisulfite and acidify with H_2SO_4 to pH 2-3/add soda ash to ppt Ca sulfate/ pH 10/neutralize with HCl		19,28	0.125

TABLE 22. (continued)

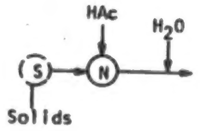
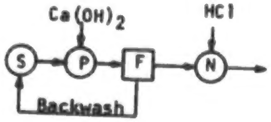
Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Sodium methylate	If neutralized		Add acetic acid to pH 7 /dilute if needed	Whenever possible send to STP/otherwise dilute/can give off CH_4/also forms NaOH in water		0.1 as NaOH
Sodium Nitrite	If oxidized	See Sodium Bisulfite				-
Sodium Phosphate (dibasic)	If diluted		Add lime to pH 11/ allow to settle (use anionic polymer if needed)/filter if necessary/neutralize to pH 7		38	-
Sodium Phosphate (monobasic)	If diluted	See Dibasic Sodium Phosphate			38	-
Sodium Phosphate (tribasic)	If diluted	See Dibasic Sodium Phosphate			38	-
Sodium Sulfide	If oxidized	See Sodium Bisulfite			10,19,33	0.75 as H_2S

TABLE 22. (continued)

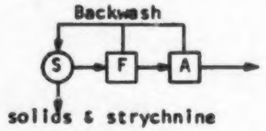
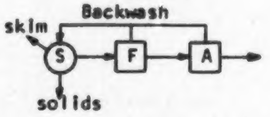
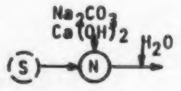
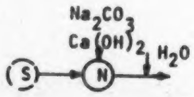
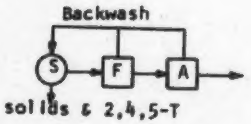
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Strychnine	no	 Backwash S F A solids & strychnine	C: 100-300 #/# sol. matl.	Dredge, pump, or vacuum undissolved portion from bottom	10	-
Styrene	If diluted	 Backwash skim S F A solids	C: 10-100 #/# sol. matl.	Skim surface of water body	10,19	21
Sulfuric Acid	If neutralized	 Na_2CO_3 $Ca(OH)_2$ S N H_2O	Add 50/50 mixture of lime and soda ash to pH 7/settle calcium sulfite sludge if needed/discharge	Be careful not to create violent reaction by too fast base addition	10,19	0.05
Sulfur Monochloride	If neutralized	 Na_2CO_3 $Ca(OH)_2$ S N H_2O	Add 50/50 mixture soda ash and lime to pH 7/allow any sludge to settle	Will decompose in water to sulfuric acid/may fume to H_2S so take special precautions	10,19	-
2,4,5-T (acid)	No	 Backwash S F A solids & 2,4,5-T	C: 100-300 #/# sol. matl.	Dredge, pump or vacuum undissolved portion from bottom	30	-
2,4,5-T	No	See 2,4,5-T acid			30	-

TABLE 22. (continued)

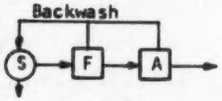
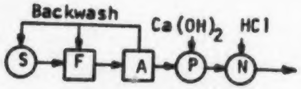
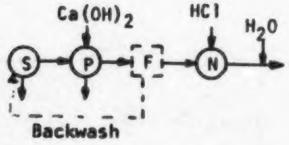
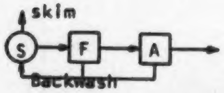
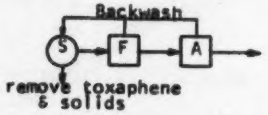
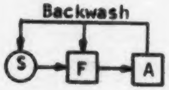
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
TDE (DDD)	no	 Backwash S F A	C: 100-300 #/# sol. matl.	Dredge, pump or vacuum undissolved portion from bottom	10,19	0.05
Tetraethyl lead	no	 Backwash Ca(OH)2 HCl S F A P N	Adsorb C: 10-35 #/# sol. matl. Add Ca $(OH)_2$ to pH 8.5/ppt lead neutralize to pH 7 if needed.	Dredge, pump or vacuum undissolved portion from bottom Carbon may be effective	10,19,33	0.05
Tetraethyl Pyrophosphate	no	 Ca(OH)2 HCl H2O S P F N Backwash	Add $Ca(OH)_2$ to pH 11 settle/filter if necessary/neutralize to pH 7/dilute	Forms phosphates and methanol when hydrolyzed untested theoretical only	*	-
Toluene	When dilute	 skim S F A Backwash	C: 10-100 #/# sol. matl.	Skim off surface of water body	10,19	18.75
Toxaphene	no	 Backwash S F A remove toxaphene & solids	C: 10-100 #/# sol. matl.	Dredge, vacuum or pump undissolved portion from bottom	30	-
Trichlorfon	no	 Backwash S F A	C: 100-300 #/# sol. matl.	Dredge or vacuum any undissolved portion from the bottom/usually will be dissolved	30	-

TABLE 22. (continued)

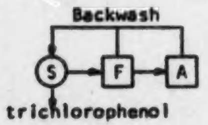
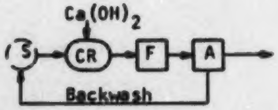
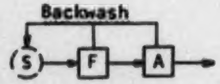
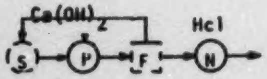
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Trichlorophenol	no		C: 10-100 #/# sol. matl.	Dredge, vacuum or pump undissolved portion from bottom	23	-
Triethylamine	When dilute		Add lime to pH 9, then run through filter. C: 35-100 #/# sol. matl.	Solubility is reduced at high temperatures	19	5.0
Trimethylamine	When dilute		C: 35-100 #/# sol. matl.	Add $Ca(OH)_2$ to pH 9/filter if necessary/neutralize to pH 7	10,19	5.0
Uranium Peroxide	no		C: 35-100 #/# sol. matl.	Uranium peroxide is a strong oxidizing agent/insoluble at pH 8/10	26*	-
Uranyl Acetate	no	See Uranium Peroxide		Uranyl acetate can also be precipitated as a phosphate	26*	-
Uranyl Nitrate	no	See Uranium Peroxide			26*	-
Uranyl Sulfate	no	See Uranium Peroxide			26*	-

TABLE 22. (continued)

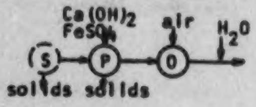
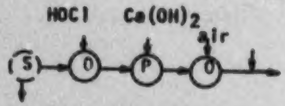
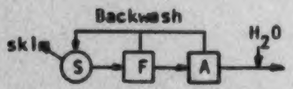
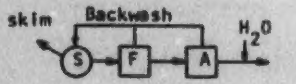
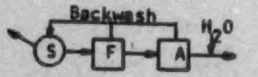
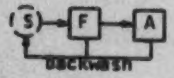
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Vandium Pentoxide	no	 $Ca(OH)_2$ $FeSO_4$ air H_2O S P O solids solids	Add $Ca(OH)_2$ to pH 8.5/ Add 4:1 Fe:V weight ratio ppt/oxidize $Fe^{+2} \rightarrow Fe^{+3}$/ will ppt $Fe(OH)_3$		26,39*	-
Vanadyl Sulfate	no	 HOCl $Ca(OH)_2$ air S O P O	Oxidize to HOCl residual add $Ca(OH)_2$ to pH 8.5/ Add 4:1 Fe:V weight ratio/ ppt/oxidize $Fe^{+2} \rightarrow Fe^{+3}$ with air/dilute		26,39*	-
Vinyl Acetate	When dilute	 Backwash skim H_2O S F A	C: 10-35 #/# sol. matl.	Skim off from water body; light may cause polymerization to solid so dredging may be required	10,19	1.5
Xylene	When dilute	 skim Backwash H_2O S F A	C: 10-35 #/# sol. matl.	Skim surface of water body	23	-
Xylenol	When dilute	 Backwash H_2O S F A	C: 10-100 #/# sol. matl.	Skim surface of water body	10,19	0.001
Zectran		 S F A backwash	C: 100-300 #/# sol. matl.		30	-

TABLE 22. (continued)

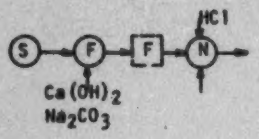
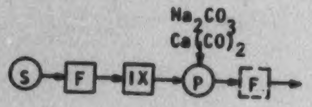
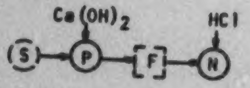
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Zinc Acetate	no		Add 50/50 mixture of soda ash and lime to pH 7.5-8.5; allow to settle/filter if needed/neutralize to pH 7	Check to assure discharge of acetate is acceptable	10,19,20, 24	5.0 as Zn
Zinc Ammonium Chloride	no		Settle/filter/exchange add 50/50 lime/soda ash to pH 7.5-8.5/settle filter if needed/neutralize if necessary	Ammonia must be removed first	24,26*	5.0 as Zn
Zinc Borate		See Zinc Acetate			10,19,20, 24,26	5.0 as Zn
Zinc Bromide		See Zinc Acetate			10,19,20 24,26	5.0 as Zn
Zinc Carbonate	no		Add lime to pH 7.5-8.5/settle/filter is needed/neutralize to pH 7		10,19,20, 24,26	5.0 as Zn
Zinc Chloride	no	See Zinc Acetate			10,19,20, 24,26	5.0 as Zn

TABLE 22. (continued)

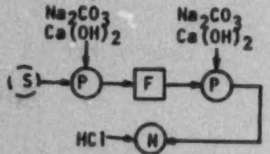
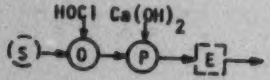
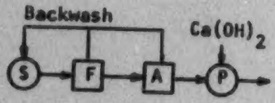
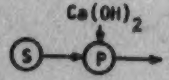
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Zinc Fluoride	no	 Na_2CO_3 $Ca(OH)_2$ S P F P Na_2CO_3 $Ca(OH)_2$ HCl N	Add soda ash to pH 7.5-8.5/settle/filter if needed/add additional soda ash/lime to pH 11/settle 24 hrs/neutralize to pH 7	F^- requires 24 hrs for removal at high pH	10,20,24	5.0 as Zn
Zinc Formate	no	See Zinc Acetate			10,19,20, 24	5.0 as Zn
Zinc Hydrosulfite	no		Oxidize with HOCl to residual/add $Ca(OH)_2$ to pH 7.5-8.5/filter if needed	Oxidize to remove hydrosulfite	10,19,20, 24,26*	5.0 as Zn
Zinc Nitrate	no	See Zinc Acetate			10,19,20, 24	5.0 as Zn
Zinc Phenol-sulfamate	no		Adsorb C: 10-100 #/#, Add $Ca(OH)_2$ to pH 7.5-8.5	Precipitation will remove any excess Zn	19,24*	5.0 as Zn
Zinc Phosphide	no		Add $Ca(OH)_2$ to pH 7.5-8.5/settle	Do not lower pH or phosphine will be formed	19,24*	5.0 as Zn

TABLE 22. (continued)

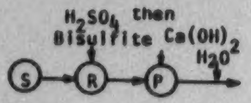
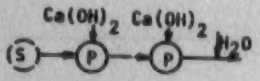
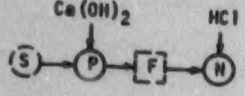
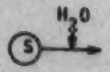
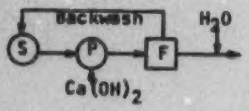
Hazardous Chemical	Amenable To Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Zinc Potassium Chromate	no	 H_2SO_4 then Bisulfite $Ca(OH)_2$ H_2O S R P	Settle to remove $ZnCrO_4$/ Add H_2SO_4 to pH 2-3, then bisulfite to large ORP or color change/add $Ca(OH)_2$ to pH 8/settle/discharge	Color changes from yellow to green Most $ZnCrO_4$ will be removed early	19,24*	5.0 as Zn
Zinc Silicofluoride	no		Add $Ca(OH)_2$ to pH 8.5/react	First lime dosage destroys silicofluoride complex test rxn carefully	19,24*	5.0 as Zn
Zinc Sulfate	no	See Zinc Acetate	Add additional lime to pH 11/settle 24 hours/dilute		10,19,24	5.0 as Zn
Zirconium Acetate	no		Add lime to pH 10/ allow to settle, filter if necessary, neutralize with HCl	Check discharge limit for Zirconium	26*	-
Zirconium Potassium Fluoride	no		Settle and dilute	A very stable complex/no other treatment recommended	26*	-
Zirconium Nitrate	no	See Zirconium Acetate			26*	-

TABLE 22. (continued)

Hazardous Chemical	Amenable to Biological Trmt. at Municipal STP	Treatment Scheme	Treatment Specifications	Comments	Reference	Prov. Limit mg/l
Zirconium Oxychloride	no		Add $Ca(OH)_2$ to pH 7/ settle/filter/dilute	May need polyelectrolyte to aid settling	26*	
Zirconium Sulfate	no	See Zirconium Acetate			26*	
Zirconium Tetrachloride	no	See Zirconium Oxychloride			26*	

5.0-CHAPTER 5 - SAFETY CONSIDERATIONS AND PROCESS DESIGN

5.1 GENERAL

5.1.1 Approach

The total section involving field implementation of treatment processes is very lengthy and for presentation in this Manual it has been divided into three sections. This first section presents sources of already constructed equipment for use in treating hazardous material spills, it also emphasizes the critical safety considerations evident in dealing with hazardous material spills and presents methods for developing the needed process design criteria. The next chapter (6) provides stepwise direction for individual design and construction of each of the five types of treatment processes. The final chapter (7) outlines needed information regarding process components such as tanks, pumps etc. and treatment chemicals. Step by step procedures are presented using cross references throughout the chapters to reduce repetition as much as possible.

Due to the complexity of treating hazardous spills and the need to make the manual as compact as possible, much desirable but not absolutely necessary information has been excluded. This procedure should not hamper the user but rather challenge him and his technical advisors to build from the basics presented here a system to suit the specific conditions and limitations with which he is faced.

5.1.2 Operation Design

It is essential that the OSC and other technical spill personnel be familiar with this Manual prior to use. Certain specific information sources have been left open and must be completed by the OSC prior to actual use of the manual. A good example is the location of local sources of materials, components, services, and supplies necessary to implement the field processes.

It is recommended that the duties at the site of the spill be divided into three distinct categories. A process engineer or director would be concerned with the process and the chemistry of the treatment. A maintenance engineer would oversee construction and then perform the necessary surveillance of the equipment to assure correct mechanical operation.

Finally, a separate safety director would be appointed whose only concern would be to attempt to provide safe working conditions in a hazardous situation. The people must work together closely to create a safe and effective working environment.

5.1.3 Format

These chapters have been structured to use various cross references in order to minimize repetition. The general approach of the three chapters is shown in Figure 37. The various chapter references are shown with the action guiding scheme. The close association with Chapter 4 is apparent. Performance of bench tests is not always mandatory since some processes don't require this procedure. However, when needed, it must be done immediately.

The chapters are based on a two-fold philosophy. The first is scaleup of the bench test results (where applicable) to allow design of a full size unit. The second, and more critical aspect of the design, is a limiting factor approach to establishing a process flow rate. In order to correctly evaluate the systems calculations are made and then the entire system should be mapped out on paper. Once this paper treatment system is "constructed", it can be evaluated in terms of the limiting factors in the specific spill situation. The procedure for applying this approach is given in subsection 5.4 in terms of questions on limiting factors and examples. In order to save time and effort on a spill site, this procedure should be followed.

Once the system flow rate has been established, construction of the treatment system can begin. The following two chapters must be used to complete this effort. The first is Chapter 6 which addresses treatment process elements and the second is Chapter 7 which addresses component selection. Chapter 7 includes criteria for selecting various types of materials used in a treatment system such as tanks, pumps, hoses, mixers, etc. The selection of specific materials is based on mechanical factors as well as the corrosivity of process and treatment chemicals. Once selection of materials and components is complete, Chapter 6 directs the construction and operation of the system. In all phases of design, construction, and operation, concern should be given to safe operation, knowing that the treatment system is, to a certain extent, a reconcentrator of the spilled substance, and therefore a reconcentrator of the hazard. In addition, chemicals used to treat the spill are, many times, hazardous materials themselves. This chapter addresses some important safety requirements which must be considered at the outset of the cleanup effort.

The sections in Chapter 7 are auxilliary portions which give additional information to the OSC. The most critical of these involves the specific details on treatment chemicals and provides examples for converting volume, weight, concentrations, etc. It is important to understand the hazards involved in handling these materials and to work safely in their vicinity. The next section covering suppliers, gives direction to the OSC regarding where specific materials can be obtained, either locally or through national suppliers. The final section presents definitions and calculations aides to help the users of the manual.

Although this portion of this Manual does include extensive cross referencing, it is the most efficient way of presenting the material. However, it does confirm the necessity of users of this Manual being completely aware of its content before use.

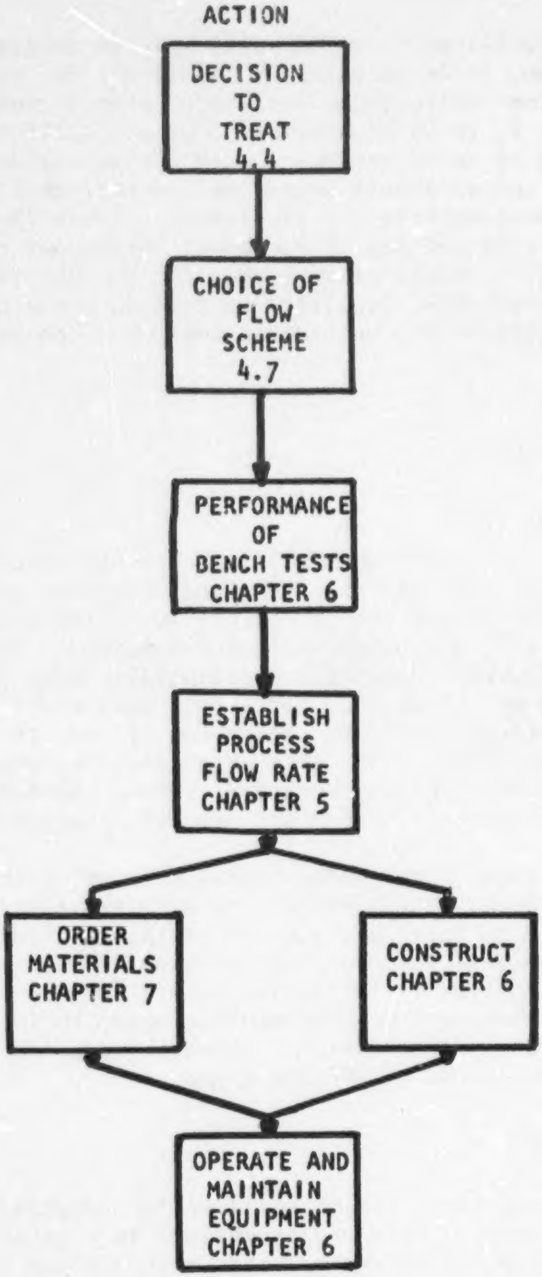

ACTION
DECISION TO TREAT 4.4
CHOICE OF FLOW SCHEME 4.7
PERFORMANCE OF BENCH TESTS CHAPTER 6
ESTABLISH PROCESS FLOW RATE CHAPTER 5
ORDER MATERIALS CHAPTER 7
CONSTRUCT CHAPTER 6
OPERATE AND MAINTAIN EQUIPMENT CHAPTER 6

Figure 37. Stepwise use of chapters 4, 5, 6 and 7.

5.2 AVAILABLE EQUIPMENT SOURCES

Once it has been established that the spill must be treated using an on-site but off-stream system, it is necessary to construct the needed process units. Prior to following the instructions for improvising a treatment system as presented in Chapter 6, it is recommended that the spill coordinator investigate the possibility of using preconstructed system components. The OSC or other authorized personnel should determine the availability of equipment to be used in hazardous material spill cleanup. Table 23 presents a list of some of the available sources of equipment throughout the country. Prior to a spill situation, it would be desirable for the OSC to be familiar with these sources and other local suppliers so that upon the occurrence of a spill, the availability of preconstructed equipment can be determined rapidly.

5.3 SAFETY PRECAUTIONS

5.3.1 Approach

Safety procedures are critical when working with hazardous materials and even more so when operating an improvised treatment system. It is critical to judiciously guard the safety of those people on the treatment site to prevent creating a disaster out of the hazard. The operators must be alerted to possible dangers and potentially hazardous situations by a specific person at the scene. Since most people will be concerned with designing, constructing, or operating the system, it seems best to choose a separate individual whose only responsibility would be safety on the treatment site. This person, hereafter termed the Safety Director, would have direct responsibility for all aspects of safety.

Among the safety director's duties are obtainment of various safety equipment, the transfer of information regarding the hazard of the situation, the specification of the level and type of protective clothing needed for each position, operation and person, and policing of the area to insure that safety standards are followed. It is the safety director's duty to work directly with the process and maintenance engineers to incorporate safety considerations into the entire system. Therefore considerable diligence and tact are necessary to do an effective job.

5.3.2 General Duties

The safety director has many responsibilities for adapting a spill site into a safe working area. These are summarized in Figure 38. In the beginning of the set-up the safety director must approve the layout of the system and the chemical and fuel storage facilities. Special instructions for storage are available in many references and these should be consulted. The safety director should also restrict access to certain areas of the treatment system by roping them off. Specific restricted areas should include chemical feed systems and any inground tanks. Warning signs should also be placed in especially hazardous areas.

TABLE 23. PORTABLE TREATMENT EQUIPMENT SOURCES

(Used chemical process equipment suppliers)

San Francisco

Machinery and Equipment Corp.
P.O. Box 3132C
San Francisco, California 94119
Phone: 415-467-3400

Houston

Dynaquip, Inc.
1143 Brittmore
Houston, Texas 77043
Phone: 713-467-5500

Petro-Power, Inc.
6436 Rupley Circle
Houston, Texas 77087
Phone: 713-644-8271

Chicago

Aaron Equipment Co.
9301 W. Bernice Street
Schiller Park, Illinois 60176
Phone: 312-678-1500

A-1 Equipment & Chemical Co.
57 East 21st Street
Chicago, Illinois 60616
Phone: 312-842-2200

Indeck Power Equipment Co.
1075 Noel Avenue
Wheeling, Illinois 60090
Phone: 312-541-8300

Loeb Equipment Supply Co.
4131 South State Street
Chicago, Illinois 60609
Phone: 312-548-4131

Union Standard Equipment
163-167 N. May Street
Chicago, Illinois 60607
Phone: 312-421-1111

Cleveland

Arnold Equipment Co.
5055 Richmond Road
Cleveland, Ohio 44146
Phone: 216-831-8485

Cleveland (Continued)

C.P.R. Machinery & Equipment Co.
5061 Richmond Road
Cleveland, Ohio 44146
Phone: 216-464-8590

Federal Equipment Co.
8200 Bessemer Avenue
Cleveland, Ohio 44127
Phone: 216-271-3500

International Power Machinery Co.
834CE Terminal Tower
Cleveland, Ohio 44113
Phone: 216-621-9514

Process Equipment Trading Co.
1250 St. George Street
East Liverpool, Ohio 43920
Phone: 216-385-2400

New York

Brill Equipment Co.
35-63 Iabez Street
Newark, New Jersey 07105
Phone: 201-589-7420

George Equipment Co.
27 Haynes Avenue
Newark, New Jersey 07114
Phone: 201-242-9000

H&P Equipment Co., Inc.
14 Skyline Drive, Box 368
Montville, New Jersey 07045
Phone: 201-335-9770

Keith Machinery Co.
34 Gear Avenue
Lindenhurst, New York 11757
Phone: 516-884-1200

Perry Equipment Co., Inc.
Box C
Hainesport, New Jersey 08036
Phone: 609-267-1600

SET-UP

Establishment of layout
Approval of storage facilities
Restriction of access
Placement of warning signs
Creating of first aid station

MATERIALS

Obtaining clean water for washing and safety uses
Ordering safety equipment
Listing emergency numbers and instructions
Providing safe lighting

COOPERATION WITH LOCAL AUTHORITIES

Aid police in restricting access
Show fire department hazard of situation

POLICE THE OPERATION (enforce safety regulations)

IMPRESS UPON PARTICIPANTS THE HAZARD OF THE SITUATION

Specific hazards of the contaminant
Specific hazards of the operation

Figure 38. Summary of a safety director's responsibilities.

While chemicals and media are being ordered, the safety director should obtain the necessary safety equipment and clothing. These materials are available from various suppliers. A discussion of these devices is included at the end of this chapter. The safety director should also obtain a source of clean water for use in washing and for emergency shower and eyewash systems. It must be stressed that all workers are dealing with a hazardous substance and should wash thoroughly prior to eating or touching anything. Finally, it is critical that the safety director instruct each person performing a specific operation with regard to its hazards and the level and type of protective clothing needed for the task.

In addition to these duties, the safety director must set up a protected safety or first aid station with a cot, blanket and first aid kit. Emergency numbers, the location of hospitals and telephone numbers of doctors in the area should also be obtained. In addition, lighting should be provided on the site if nighttime operation is expected.

The safety director should also work with local authorities--police, civil defense and fire department--to establish procedures for both emergency and normal operating situations. Police may be able to restrict access of unauthorized persons to the site, while both civil defense and fire department officers should inspect the system prior to the development of any emergency situation. The safety director should be familiar with the hazards of the specific contaminant being treated. He must have knowledge of antidotes or special safety procedures to insure that adequate precautions are taken. This information must then be conveyed both to local emergency authorities and to the people working at the site.

Once the system is operating, the safety director must inspect the area regularly, and check to make sure the system and the people are working safely. All treatment equipment should be inspected as should the protective clothing worn by operators.

However, it is more important for the safety director to impress upon the operators of the equipment the importance of system safety. The various situations which present specific hazards should be explained and the possible affects made known to the workers. If this is done effectively, safety will be a concern of all people on the spill site and accidents can be avoided or minimized.

5.3.3 Specific Operating and Maintenance Hazards

There are many inherent safety problems which arise when a jury-rigged system is operated. The following sections indicate some of the situations which require special attention. Once on the scene, a safety director should be able to notice many more. It is necessary to warn the person performing the task of the specific hazards involved and help him to minimize them.

5.3.3.1 Desludging - The desludging operation involves transfer of a concentrated and highly contaminated sludge. In general, the job is messy and difficult. All personnel involved in this task should wear protective clothing and eye protection as specified by the safety director and avoid unnecessary contact with the sludge.

5.3.3.2 Hose Repositioning - Moving hoses may be a necessary task and it may be difficult to do without showering the area (and people) with contaminated liquid since hoses can easily get loose. When hoses are to be moved, the pump feeding them should be shut off and for extra safety the person moving the hose should wear protective clothing and eye protection, specified by the Safety director.

5.3.3.3 Tank Patching - When tanks require repair, this must usually be done from the inside of the tank and therefore may involve direct contact with the contaminant. Two people should be involved in the operation and both should be equipped with specified protective clothing and goggles. One person must enter the drawn-down tank while the other can stay outside to assist in any manner necessary. However, extreme caution is needed to avoid falling since the tank bottom liner may be quite slippery.

5.3.3.4 Pump Handling - Pumps must be watched at all times, so flow can be shut off immediately to avoid downstream problems. When hoses on pumps are removed, it is necessary to fully relieve the pressure which builds up at the pump to avoid blow back of the wastewater. The pump operator should be equipped with protective clothing and eye protection to avoid injury from this situation. The raw flow pump is also very difficult to set up and handle, so operators should be protected and take special precautions.

5.3.3.5 Hoses and Fittings - Another problem involves slippage between hoses and fittings which occurs during operation. To minimize the problem a maintenance director can check these systems throughout the day and retighten them as necessary. Anyone in the vicinity should be protected to avoid contact with the contaminant in case the hose breaks loose.

5.3.3.6 Chemical Feed System - The handling of treatment chemicals and the chemical feed system is a very dangerous operation in a jury-rigged system. Specific cautions and problems are indicated in Chapter 7, however certain general rules should be followed. The chemicals should not be touched under any circumstances and a respirator should be used if dust is present. Eye protection, gloves and rubber aprons or specified protective clothing are necessary for anyone operating the feed pump or mixing chemicals. As stated previously, the area should be restricted and access granted only to those wearing proper safety equipment. The hoses for chemical systems must be well supported so that they don't loosen and spray chemicals on unprotected individuals. In addition, hoses, fittings and pumps should be inspected frequently and any leak fixed immediately. These chemicals can present a personal hazard equal to or greater than exposure to the contaminated liquid because of the high concentrations involved. Therefore, the safety director must stress this fact to all people concerned with treatment and strictly enforce the safety regulations.

5.3.4 Commercially Available Safety Equipment

5.3.4.1 General - The safety equipment previously referred to will be described in this section. This equipment is commercially available and a number of vendors are given at the end of this discussion. The needed safety materials should be ordered and kept on hand by the OSC, by responsible agencies such as police and fire departments, and by contractors involved in hazardous material spills cleanup.

5.3.4.2 Testing Equipment - Testing of the air is often advisable at the scene of the spill to determine if a combustible, toxic or oxygen deficient atmosphere exists. While there are varying degrees of sophistication, portable instruments which would be of the most use include:

1. Universal tester - tests for a wide range of toxic gases.
2. Combustible gas indicator - measures combustible gases or vapors.
3. Oxygen indicator - tests for concentration of oxygen.

5.3.4.3 Protective Clothing - Protective clothing available includes respiratory devices, suits, gloves, hoods, shoes and boots. A comprehensive inventory of much of this equipment is available in the U.S. GPO Publication "A Survey of Personnel Protective Equipment and Respiratory Apparata for Use by Coast Guard Personnel in Response to Discharges of Hazardous Chemicals" (NTIS ADA - 010-110)(42). In addition to listing of available safety equipment, a prototype of the Coast Guard fully protective suit is included. This document should be obtained for use by the safety director at the spill site. Respiratory devices include atmosphere supplying breathing apparatus, gas masks and other types of respirators (dust, mist or paint spray, etc.). Breathing apparatus have their own source of air or oxygen rather than attempting to purify and use the ambient, contaminated air. Breathing apparatus are the safest and recommended type of respiratory protection and should be used unless it is confirmed that the contaminant can be removed by a filter or canister. A breathing apparatus provides general protection against toxic gases and oxygen deficiency. The most commonly used breathing apparatus is the self-contained air mask. A cylinder of air is carried on the back of the user and is supplied on demand. Exhaled air is exhausted to the surrounding atmosphere.

Gas masks provide protection against a specific hazard when equipped with the appropriate chemical-sorbent canister. Canisters are available to protect against low concentrations of acid gases, organic vapors, carbon monoxide, ammonia, and chlorine. In no case should a canister gas mask be used if there is a chance that the concentrations may exceed the sorbent limit or that an oxygen deficiency may exist.

The protective suits (thought of as completely enclosing the wearer) provide the maximum protection against a hazardous environment. There is no suit commercially available which is resistant to all hazardous chemicals. The Coast Guard is developing a butyl rubber maximum protection suit and the U.S. EPA is developing a lightweight butyl rubber suit. Once the hazard is known, however, appropriate clothing usually can be selected from what is commercially available. In most cases this will be acid resistant clothing, i.e., fabric coated with vinyl, butyl, or neoprene rubber. A typical commercially available suit consists of a neck-to-toe, one piece coverall and a separate hood. Air is supplied to the suit from an outside source. Less restrictive garments are also available but provide less protection.

Coated gloves are available to protect against various chemicals. Hard hats should be worn if there is a danger of falling objects or low-clearance bump hazards. Hard toe boots and shoes should be standard items. However, it must be stressed that protective clothing is only effective when the identity of the spill is known and when the clothing is properly used. If the specific hazard is not known, a fully protective suit may not provide long term protection for working in the spill vicinity. The hazard associated with improper use of protective clothing is obvious.

5.3.4.4 Eye Protection - Eye protection in the form of safety glasses or goggles should be required of everyone on the site of a spill cleanup. Unlike some street glasses, safety glasses have lenses that are impact and shock resistant. Side-shields or goggles are recommended if corrosive chemicals are to be handled or pumped.

5.3.4.5 Skin Protection - Skin creams are available for protection against specific types of irritants. These irritants include acids, alkalies, tar, and cooling and cutting oils.

5.3.4.6 First Aid Equipment - A first aid kit should be kept at the site of the spill cleanup. A portable resuscitator may also be in order depending on the hazards involved.

5.3.4.7 Vendors - Safety equipment is available from the following vendors (among others):

Mine Safety Appliances Company
400 Penn Center Boulevard
Pittsburgh, Pa. 15235
412-241-5900

Environmental Tectonics Corp.
4 James Way
County Line Industrial Park
Southampton, Pa. 18966
215-355-9100

Additional equipment may be found locally by checking the Yellow Pages under Safety Equipment and Clothing.

5.4 SYSTEM DESIGN CRITERIA

5.4.1 General

Once it has been established that the spill must be treated on site in an offstream treatment system, many considerations must follow. The first design step is to establish the process flow rate of liquid through the treatment system before further design can be started. Various factors affect the flow rate including time, site considerations, material availability, manpower requirements and the characteristics of the contaminated liquid itself. It is best to consider each spill situation individually and evaluate which factors limit flow in that spill occurrence. This section presents the various factors and then applies examples to indicate how the site and material problems can be solved using the built-in flexibility of a parallel batch system. However the section does not attempt to judge a situation, but rather to present circumstances which may occur to make the OSC aware of these limiting factors.

5.4.2 Limiting Factors in System Design

Many factors are used to establish the maximum possible flow rate through a specific treatment system. Some of the variables are outlined in Figure 39. They have been divided into six general headings and each of these will be discussed in the following sections.

5.4.2.1 Time - For many spill situations, time is a critical factor for various reasons. In some circumstances there is immediate danger or a change in weather conditions will create a more severe problem by spreading the spill, so treatment must be completed before the next precipitation event. Possibly, the men on site are only available for a limited amount of time or the local authorities insist the spill must be cleaned by a certain time. In any event, once a time is established, and the volume of spill is known, then a process flow rate can be calculated.

5.4.2.2 Site Considerations - A new set of factors is introduced when the site is being considered. If the spilled material is extremely hazardous, a treatment site near the spill may be dangerous and the available pumping capacity may be insufficient to convey the contaminated liquid to a treatment system located a far distance from the spill itself. Another consideration is accessibility to the spill site by vehicular traffic (i.e. trucks) to allow equipment, supplies and manpower to reach the site. Other important considerations involve the amount of firm, flat and clear area available for construction of tanks and other large area requiring equipment. Modifications of the site with earth moving equipment or fill may be needed to allow a sufficient area to provide the required capacity of the treatment system.

Other problems involved in site considerations are the proximity to residences and roads. Residential interference may create problems when

TIME:

Immediate Danger
Meteorological Conditions
Local Political Considerations

SITE CONSIDERATIONS:

Safe Proximity to the Spill
Accessibility by Vehicles
Clear Area
Flat Area
Firm Ground
Number of Setups Requires
Proximity to Residences
Restriction to Civilian Vehicular Traffic

MATERIAL AVAILABILITY:

Sufficient Tankage
Sufficient Pump Transfer Capacity
Media Availability
Chemical Availability
Special Equipment Availability

PROCESS RESTRICTIONS:

Long Detention Time in Sedimentation
Difficulty in Desludging
Long Contact Times Required in Columns
Large Volumes of Sludge Obtained

MANPOWER LIMITATIONS:

Sufficient Skilled Labor for Construction
Sufficient Labor for Operation

MISCELLANEOUS PROBLEMS:

Degree of Contaminant
Available Hauling Capacity

Figure 39. Limiting factors in system design.

24 hour per day operation is desirable or nearby roads may require special police or DOT provisions. Finally if the spill extends over a long distance, the number of times the treatment system must be set up has to be considered. A central but relatively remote location may be absolutely necessary to avoid reconstructing the treatment system at another site.

5.4.2.3 Material Availability - Once a flow rate has been estimated, the amount of construction materials and chemicals needed to meet this goal can be calculated. At this point, various parts of a treatment scheme may completely limit the flow through rate. These requirements are also directly related to the contaminated liquid treatment characteristics. In general, the most common limiting factor will be the availability of sufficient tankage to handle the spill. This required tank volume will also directly affect the area needed for treatment as discussed previously. Another consideration is the availability of sufficient pump capacity for transfer from the liquid source through the treatment processes and back to a receiving body of water together with the requirements of the chemical feed system and desludging operations.

In some situations, special equipment is needed to allow the safe handling of corrosive material and this special supply may be limiting. Finally, the availability of treatment chemicals and column media may affect the overall flow rate. However, it must be remembered that partial orders can be shipped before the complete order to reduce this problem.

5.4.2.4 Process Restrictions - The treatability of the contaminated liquid will also affect the design of the treatment system. A slow settling liquid will require more tankage. Also a sludge which is bulky or difficult to remove or pump from the tank will increase the number of needed tanks. The specific hazardous material being removed may need longer column contact time (especially for carbon) or may require removal to a higher degree. Finally, the characteristics of the contaminated liquid may result in a large volume of bulky sludge to be removed daily.

5.4.2.5 Manpower Limitations - There are two types of general labor required, although both functions can be filled by the same people. The first is the labor required for construction of the treatment plant within a short period of time. Local contractors can generally provide assistance in this area. The other manpower requirement is for the actual operation of the treatment system. Table 24 summarizes the approximate manpower needed for each operation on a per shift basis. However, prudent scheduling or a reduced working day may reduce the number needed. In general, based on 8-10 hr./day of work, each pump requires at least one person to operate it and column operation may need more manpower. Supervisory manpower must also be included and should include at least 3 people: process director, maintenance director and safety director plus some personnel to aid in process control functions.

Table 24. MANPOWER REQUIREMENTS FOR VARIOUS UNIT PROCESSES PER SHIFT

	Manpower	Job Description
1. Sedimentation	1	Fill tanks
	1	Empty tank
	1	Change hoses
	1	Desludging
	4	
2. Filtration	1	Run influent pump
	1	Watch columns for loading
	1	Backwash
	3	
3. Ion Exchange	1	Run influent pump
	1	Watch columns for loading
	2	
4. Carbon Column	2	Run influent pump
	2	Watch columns for loading (1 bank each)
	4	
5. Chemical Reaction	1-2	Chemical feed
Oxidation	1	Mixer
Reduction	1	Run influent pump
Sedimentation	1	Run effluent pump
Neutralization	1	Run flocculating unit
	1	Test endpoint
	1	Desludge (opt.)
	7-8	

5.4.2.6 Miscellaneous Problems - Other problems can also affect the flow rate. If the containment is not complete, the total overflow from the spill must be treated or held for treatment. Another consideration is the availability of hauling vehicles for sludge removal and the availability of the disposal site. If the proposed sludge volume per day is too voluminous, the flow rate must be reduced.

5.4.3 Parallel/Batch System Use

The use of the parallel batch operation does add flexibility to the system. If the scale-up of the process changes from that which is expected or if maintenance problems occur, the addition of tanks in parallel can compensate for these problems. The systems are set up in banks of tanks and filters served by pumps fitted with flow splitters and then equalization tanks between processes. If more capacity is needed, more tanks can be added to the operation without changing much of the basic design criteria. The examples which follow indicate how these systems can be modified with various limiting factors.

5.4.4 System Flow Scheme Construction

5.4.4.1 General - Once the flow scheme has been chosen, there are some construction steps which are not apparent from the original schematic. Additional tanks for equalization between processes and specific process logistics are necessary for efficient operation of a treatment system. Therefore various procedures have been recommended and are discussed in the following sections.

5.4.4.2 Equalization Tanks - Addition of equalization tanks between processes will simplify the operation of a batch and continuous flow integrated system. It also provides a safety factor and extra storage in a malfunctioning process. These tanks are not necessarily large, but they should hold a sufficient amount of liquid between the units to smooth out the flow rates. In general, an equalization tank is placed before and after each unit process. For column operation, the calibrated equalization tanks can be used to regulate the loading rates.

5.4.4.3 Carbon Column Series Operation - Design of efficient carbon column operation is established by two criteria of equal importance. One criteria is the loading rate to a column and this variable is a function of the surface area of the column itself. The other variable is the contact time between the carbon and the contaminated liquid and this factor is a function of the depth of carbon in the column and the loading rate. It is necessary to provide a minimum contact time of thirty minutes for removal of contaminants, however, the loading rate of 81.41/min/sq. m or (2gpm/ft^2) will only allow a fifteen minute contact time when the carbon depth is limited to 1.22m (48") (See Section 6.3.2.) Therefore, to increase the contact time a second column can be used in series with the first column and this can be visualized as a tall column split into two shorter columns for easier operation. However, the surface area of the second column is not to be considered in the calculation of the required surface area. Another way to increase the contact time is to decrease the loading rate to 40.71/min/m^2, however, use of series operation at 81.41/min/sq. m or (2gpm/ft^2) has several advantages. These are: 1) additional contact time to 60 minutes can be obtained by reducing the loading rate if necessary and more importantly, 2) the exhaustion of carbon can be monitored at the effluent from the first column to establish the actual breakthrough time and still provide removal through the second column.

A schematic of the carbon column operation as recommended is shown in Figure 40.

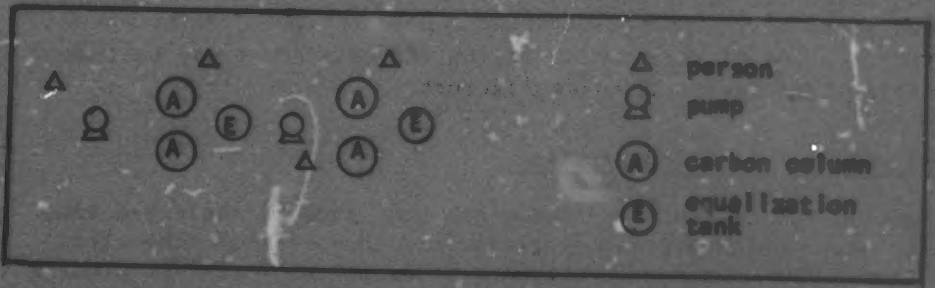


Figure 40. Schematic of carbon column operation.

In this operation, however, there are requirements for additional manpower, number of pumps and equalization tanks.

5.4.4.4 Pump Requirements - Transfer of the contaminated liquid from the water body to the treatment system, through the process and then back to the environment is done using pumps. Specific details on pump choices are given in Chapter 7, Figure 41, however, the number of pumps needed and the required capacity are established in this system design section. Using pumps in a batch system requires a single pump which is operated at a flow equal to or higher (if possible) than the system's design flow rate. Tanks are filled, then hoses are switched to another tank to keep the operation as continuous as possible, therefore, one influent and one effluent pump are used for any number of tanks. Column operations are also fed by one pump which operates at the system's design flow rate, however, a flow splitting device is used to divide the flow and allow correct loading rates. Miscellaneous pumps necessary include individual chemical feed pump for each chemical added, mixing pumps, desludging or solids handling pumps, and a final pump to return the effluent to the water body. The pump requirements and schematics are shown in Figure 41.

5.4.5 Examples of System Design

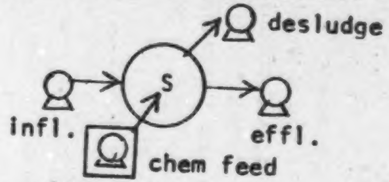
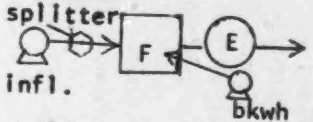
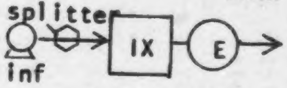
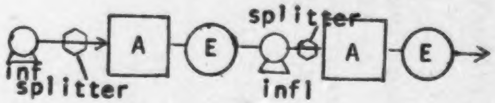
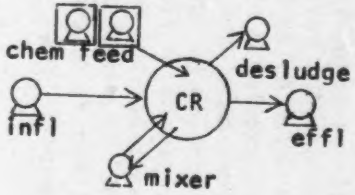
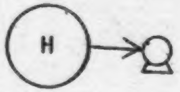
Process	No. Pumps	Approximate Configuration
Sedimentation	1 - Influent 1 - Effluent 1 - Solids Handling 1-2 - Opt. Chem. Feed	 desludge S infl. effl. chem feed
Filtration	1 - Influent 1 - Backwash	 splitter F E infl. bkwh
Ion Exchange	1 - Influent	 splitter IX E inf
Carbon Column	2 - Influent	 inf splitter A E splitter infl A E
Chemical Reaction	1-2 - Chemical Feed 1 - Influent 1 - Effluent 1 - Mixer 1 - Desludge	 chem feed desludge infl CR effl mixer
Holding Tank	1 - Effluent	

Figure 41. Pump requirements for unit processes.

5.4.5.1 General - The following examples show a general approach to system design. After bench scale tests have been performed on the contaminated liquid, and a flow scheme chosen, a detailed schematic is developed. A summary of the equipment requirements for the various unit processes is shown in Figure 42. The user must keep in mind these requirements and the information presented in Section 5.4.4 when developing the preliminary schematic.

Once the schematic is established, then calculations are begun to establish the design flow rate. An initial approach is to choose an approximate time which is to be considered limiting (if one does not already exist) to provide a starting point for calculations. Once the design has been completed at that flow rate, then the various limiting factors should be considered. These were discussed in Section 5.4.2 and are presented in Figure 43 as questions to be considered by the user after a design has been completed. Answering these questions will force the OSC to evaluate the entire system prior to construction and allow a decision to be made as to whether the initial design flow rate can be attained or not. This procedure is outlined in the examples which follow.

5.4.5.2 Example: Endrin Spill -

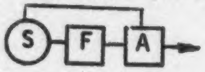
Note: All calculations are in English units, the following conversions are appropriate.

lbs × 0.454 = kg
ft × 0.305 = m
gal. × 3.785/1000 = cum
$ft^2 \times 0.093 = m^2$
gpm × 3.785 = lpm

SECTION REFERENCE

Scene: A train car has derailed and spilled ten 45 gallon drums of Endrin into a pond. The spill has been contained within the pond, however a long range weather forecast indicates storms are expected in 7 - 10 days. It has been decided to treat the water column and dredge the bottom separately but the local suppliers have only six 5' diameter tanks available for use in treatment construction. Calculate the design flow rate and system logistics to treat the water column.

1. Choose Appropriate Flow Scheme — Table 22



Carbon 100-300 #/#

Gravity Separation

1. Tanks - equalization, process, chemical storage
2. Desludging/Skimming Equipment
3. Chemical Feed System (opt.)
4. Mixing Equipment (opt.)
5. Flocculation Device (opt.)
6. Chemicals (opt.)
7. Pumps - raw flow pumps, solids handling
8. Sludge or Scum Tanks
9. Sampling Equipment

Column Operation

(Filtration, carbon, adsorption, ion exchange)

1. Tanks - equalization, process
2. Pumps - influent, solids handling
3. Flow Splitter
4. Media
5. Sampling Equipment
6. Fines Skimming Device
7. Underdrain system - bricks, grating, gravel, sand
8. Equalization Tank (after)

Chemical Treatment

General

1. Tanks - equalization, process, chemical feed
2. Chemical Feed System
3. Pumps - solids, raw flow, chemical feed
4. Mixing System
5. Flocculation System (opt.)
6. Chemicals
7. Chemical Testing Kit

Neutralization

1. pH Meter

Precipitation

1. Desludging System
2. pH Meter
3. Sludge Tanks

Oxidation/Reduction

1. ORP Meter (if possible)
2. Chlorine Testing Kit (opt.)
3. Spot Plate Chemicals (opt.)

Figure 42. Equipment requirements by process element.

1. Is time limiting?
    a. Is there an immediate danger or limiting period of time before a hazard exists?
    b. Do meteorological conditions impose a time limit?
    c. Do local political situations impose a time limit?
    d. Do other circumstances impose a time limit?

2. Is the site limiting?
    a. Can the treatment site be located close enough for pumping?
    b. Is the site accessible by truck?
    c. Is sufficient clear area available?
    d. Is sufficient flat area available?
    e. Is the ground firm enough to hold the treatment system?
    f. Are too many set ups needed?
    g. Is the site close to residences which impose various other restrictions?
    h. Does the site impede vehicular traffic?

3. Materials available?
    a. Is sufficient tankage available (volume, number, type)?
    b. Can pump transfer capability be obtained?
    c. Is column media available?
    d. Are chemicals available?
    e. Is special equipment necessary and available?

4. Process Restrictions?
    a. Is an extra long time needed in sedimentation?
    b. Is the sludge difficult to remove?
    c. Are longer contact times required in the columns (especially carbon)?
    d. Are large volumes of sludge generated?

5. Is manpower limiting?
    a. Is there sufficient skilled labor for construction?
    b. Is there sufficient labor for operation?

6. Are other problems apparent?
    a. Is the degree of containment sufficient to allow a chosen flow rate?
    b. Is there sufficient hauling capacity available for sludge?

Figure 43. Questions to establish limiting factors.

SECTION REFERENCE

II. Do Bench Scale Tests

Only settling tests were performed on the water column which contained algae with entrained endrin. This material must be removed prior to carbon column adsorption since it exerts a large carbon demand. The results are as follows:

Flocculation time = 5 min.
Settling rate = 0.5 fpm
Sludge volume = 1.3% of influent flow
Sludge height = 0.5 cm.
Cylinder height = 36.5 cm.
Polyelectrolyte dose = 2.0 mg/l

III. Develop an Appropriate Schematic

1. Establish number of pumps — Figure 41

   Explanation: Each process (or bank of tanks) requires an influent pump. Since carbon adsorption is done in series, it requires two influent pumps. An effluent pump is used after the final holding tank.

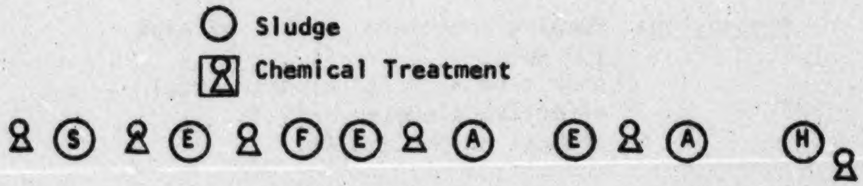
2. Place equalization tanks, denoted E , between the unit processes

   Explanation: These additional tanks will simplify the operation.

3. Use dashed lines to indicate possible process tanks.

4. Place a holding tank at end of the system for effluent storage

5. Draw diagram:



IV. Calculate Desirable Flow Rate.

SECTION
REFERENCE

Assumptions: a. 7 day time limit
b. 1,000,000 gal. to treat

$$\text{Flow rate} = \frac{\text{Vspill}}{\text{time to treat}}$$

$$= \frac{1{,}000{,}000 \text{ gal.}}{7 \text{ day} \times 16 \text{ hr/day} \times 60 \text{ min/hr}}$$

$$= 148.8 \text{ gpm} \sim 150 \text{ gpm}$$

Explanation: Assume a design day of 16 hours for treatment although actual operation may be longer to treat backwash. Experience has indicated that a jury-rigged system will require large amounts of maintenance and that backwashing and desludging is more easily accomplished during down time.

V. Establish Number of Sedimentation Tanks Required 6.5.4

1. Apply data from settling test to establish detention time

$$\text{det. time} = \frac{\text{process height}}{\text{settling rate}} \times 3 \text{ (safety factor)}$$

assumption: Hp = 3 feet
settling rate = 0.5 fpm

$$\text{det time} = \frac{3 \text{ ft.} \times 3}{0.5 \text{ fpm}}$$

$$= 18 \text{ min:}$$

flocculation time = 5 min.
total detention time = 23 min.

2. Calculate fill and draw time

Assumption: Pumping rate into and out of tank 150 gpm
tank type - 20 ft. diameter pool
effective diameter = 19 ft.
process height = 3 ft.

$$\text{Tank volume, } V_n = \frac{\pi D^2}{4} \times H_p \times 7.48 \frac{\text{gal}}{\text{ft}^3}$$

SECTION REFERENCE

$$= \frac{3.14 \times (19)^2 \text{ ft}^2 \times 3 \text{ ft} \times 7.48 \frac{\text{gal}}{\text{ft}^3}}{4}$$

$$V_n = 6360 \text{ gal.}$$

$$t_{fill} = t_{draw} = \frac{V_n}{\text{Pumprate}} = \frac{6360}{150} = 42.5 \text{ min.}$$

$$T_T = \text{total time} = 23 \text{ min} + 2\,(42.5) = 108 \text{ min.}$$

Explanation: Although a filling and drawing rate of 150 gpm is necessary when working through the design steps, it is recommended that higher rate pumps actually be used for shorter durations, allowing time in between batches to move hoses, pumps, do maintenance, etc.

3. Establish frequency of desludging

$$\text{time between desludging} = \frac{0.25 \times H_p \times T_T}{\dfrac{\text{accumulation of sludge}}{\text{batch}}}$$

$$\frac{\text{accumulation of sludge}}{\text{batch}} = \frac{0.5 \text{ cm}}{36.5 \text{ cm}} \times 3 \text{ ft.} = .014 \times 3 \text{ ft.}$$

$$= 0.041 \text{ ft.}$$

$$\text{time between desludging} = \frac{0.25 \times 3 \text{ ft.} \times 108 \text{ min.}}{.041 \text{ ft} \times 60 \text{ min/hour}}$$

$$= 33 \text{ hours}$$

However desludging can be performed after the 16 hour operating period (i.e. during the 8 hour down time).

4. Calculate reduction in tank volume caused by sludge accumulation.

$$\text{Amount of sludge accumulated between desludgings} = \frac{\text{amount of sludge}}{\text{batch}} \times \frac{\text{batches}}{\text{before desludging}}$$

SECTION REFERENCE

$$\text{amt. of sludge accumulated} = \frac{0.041\ \frac{\text{ft}}{\text{batch}} \times 16\ \frac{\text{hr/between}}{\text{desludging}} \times 60\ \text{min/hour}}{108\ \text{min/batch}}$$

$$= 0.37\ \text{ft./between desludging} \sim 0.4\ \text{ft.}$$

Effective process heights =

Hp - amount of sludge accumulated between desludgings
= 3 ft - 0.4 ft = 2.6
and the corrected tank volume (V_{peff}) is therefore:

$$\frac{(19)^2\ \text{ft}^2 \times 3.14 \times 2.6\ \text{ft} \times 7.48\ \frac{\text{gal}}{\text{ft}^3}}{4}$$

$V_{(peff)} = 5500$ gal.

Explanation: This height is then equal to the actual effective process height after reducing for accumulated sludge over the time period. The total sludge will not accumulate to this height until the end of the day so the average is 0.5 times the total accumulation. However drawoff can only be done to a level approximately twice as high as the sludge layer. Therefore the effective reduction is the following:

2 x (0.5 x height of sludge for drawoff) = height of sludge.

5. Calculate process volume required

$Vp = Qp\ (T_t)$

Vp = 150 gpm x 180 minutes = 16,200 gal.

6. Calculate number of tanks needed

$n = Vp/Ve$

$$= \frac{16200\ \text{gal.}}{5500\ \text{gal/tank}}$$

= 3 tanks

VI. Calculate the Number of Filters Needed. 6.2.2

Assumption: loading rate = 4 gpm/ft^2
diameter of filter = 5'

SECTION REFERENCE

1. Calculate surface area of 1 filter

surface area $= \frac{\pi D^2}{4}$

$= \frac{3.14 \times (5)^2 ft^2}{4}$

$= 19.6\ ft^2$/filter

2. Calculate surface area needed based on flow rate

surface area $= \frac{Qp}{4 gpm/ft^2}$

Surface area $= \frac{150\ gpm}{4\ gpm/ft^2} = 37.5\ ft^2$

3. Calculate the number of filters needed

number of filters $= \frac{\text{surface area}}{\text{surface area/filter}}$

$= \frac{37.5\ ft^2}{19.6\ ft^2/\text{filter}}$

$= 1.9$

$= 2$ filters

VII. Calculate the Number of Carbon Columns Needed 6.3.2

Assumptions: diameter = 5' surface area = $19.6\ ft^2$

surface loading = $2\ gpm/ft^2$

a. calculate surface area needed: $\frac{Qp}{2 gpm/ft^2}$

$\frac{150\ gpm}{2\ gpm/ft^2} = 75\ ft^2$

b. calculate the number of columns

$\frac{75\ ft^2}{19.6\ ft^2\ /\text{column}} = 3.8$

= 4 columns

c. Total number = 2 x 4 columns = 8 columns

SECTION REFERENCE

Explanation: Carbon columns are used in series to provide the required contact time so the second column is not included in the surface area calculation.

VIII. Design the Holding Tank

Assumptions: Hold about 30 min. flow, pump into and from tank at 150 gpm.
Use 20' diameter tank
Use 19' feet effective diameter
H_p = 3 ft

$$\text{Volume}_n = \frac{(19)^2\,\text{ft}^2 \times 3.14 \times 3\,\text{ft} \times 7.48\,\text{gal}}{4 \qquad\qquad \text{ft}^3}$$

$$= 6360\ \text{gal.}$$

$$\text{Time to fill and draw} = \left(\frac{V_n}{\text{pumping rate}}\right)$$

$$= \frac{6{,}360\ \text{gal.} \times 2}{150\ \text{gpm}}$$

$$= 85\ \text{minutes}$$

T_T = 85 + 30 = 115 minutes
V_p = 115 minutes × 150 gpm
= 17,250 gal.

$$\text{Number of tanks} = \frac{V_p}{V_n} = \frac{17{,}250}{6{,}360} = 2.7$$

Use 3 tanks

Explanation: If possible the OSC should determine if 2 tanks and a shorter holding time is sufficient.

IX. Design Sludge Holding Tank 6.5.4.

Calculate sludge volume for one day of operation.

Assume the volume to be stored is twice the actual volume of sludge produced since it is recommended that drawdown only go down to twice the actual sludge depth.

depth of sludge for storage = 2 × 0.40 ft. = 0.8 ft.

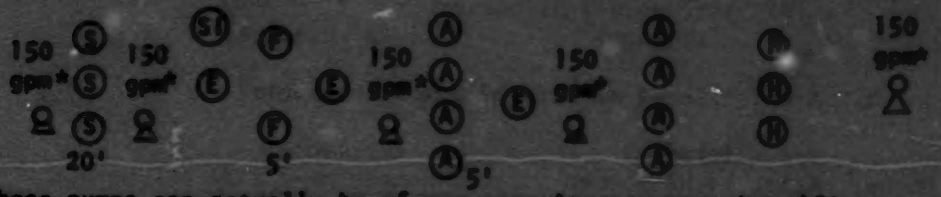
volume of sludge for storage from 3 sedimentation tanks $= \frac{(19)^2 \text{ ft}^2 \times 0.8 \text{ ft} \times 3.14 \times 7.48 \text{ gal.} \times 3 \text{ tanks}}{4 \qquad\qquad \text{ft}^3}$

SECTION REFERENCE

= 5087 gal. required

one 20' diamter tank holds 6360 gal. so 1 tank is sufficient

X. Revise the Schematic:



* These pumps can actually be of any capacity greater than 150 gpm; the greater the capacity the shorter the duration of their operation.

XI. Evaluate the Limiting Questions

Figure 43

1. Time limits - No problem since the flow rate was established based on this criteria.

2. Site considerations

a. Safe proximity?
Answer: Yes, it is safe to approach and treat.

b. Accessible by truck?
Answer: Yes.

c. Is area clear/flat/firm and available?
Answer: The amount of area required can be estimated be assuming 5' between large tanks and 2' between small tanks and then adding the distances from the schematic. In this case an area 105 ft. x 85 ft is needed and is available.

d. Are residences or roads near by which would restrict operation or operating hours?
Answer: No.

e. How often must the treatment system be set up and can the site be centrally located:
Answer: The site can be centrally located and set up only once.

3. Material availability

SECTION REFERENCE

a. Are enough tanks available?

number needed			number available
			1-25' diameter
20'	9	(sedimentation/sludge/ 1 equalization/holding tank)	0
5'	10	(columns)	6
10'	3	(2 equalization/carbon storage)	2 1-18' diameter

b. Are sufficent numbers of pumps available? 7.2

Number	see references Rates to be pumped	Available number pump size
3	$\geq$ 150 gpm	3 - 400 gpm
3	- 150 gpm	3 - 150 gpm
1	- 25 gpm backwash	1 - 50 gpm
1	50 gpm solids pump	1 - 100 gpm

c. Is media available? 6.3.2

Amount needed = 100-309 #/# of soluble material.

Solubility of endrin = 0.19 mg/l in water

Volume of spill = 1,000,000 gal.

$$\text{lbs of Endrin} = \text{volume (MG)} \times 8.34 \frac{\text{lb}}{\text{MG-mg/l}} \times \text{solubility in mg/l.}$$

$$= 1 \text{ MG} \times 8.34 \frac{\text{lb}}{\text{MG-mg/l}} \times 0.19 \text{ mg/l}$$

= 1.58 lbs of Endrin is soluble, the remainder is entrained or sunk.

Amount of carbon to order =

1.58# x 300#/# of soluble Endrin = 475 lbs.

Answer: Yes. Carbon is available.

d. Are chemicals for flocculation available?

Amount of chemicals needed;

polymer added; $$\frac{2.0\ \text{mg}/\ell \times 3.785\ \ell/\text{gal.} \times 10^{6}\ \text{gal.}}{453.6\ \text{gr}/\# \times 1000\ \text{mg}/\text{gr}}$$

lbs of polymer = 17 lbs needed

Answer: Yes. Chemicals are available.

e. Does spill require special equipment?
Answer: No.

4. Process restrictions

a. Is the detention time too long?
Answer: A 23 min. detention time is not too long.

b. Are problems involved with desludging?
Answer: No apparent problems for water column treatment.

c. Long contact time needed in column?
Answer: No. Endrin will adsorb well.

d. Are large volumes of sludge obtained?
Answer: No. Only 1.3% of influent volume is estimated to become sludge.

5. Manpower limitations

a. Construction: 10 people are available - enough people.

b. Operation: See Table 24. The number of people needed per shift of operation is as follows:

sedimentation - 3	carbon - 4
filters - 2	effluent pump - 1

Add 3 people for safety, process and maintenance directors.

13/shift and 2 shifts/day for operation

c. Downtime crew

This crew should equal the number of people on the operating crew during one shift. In this case 10 people.

d. Total manpower in operation = 26 + 10 = 36 people

SECTION REFERENCE

6. Miscellaneous

   a. Is the spill sufficiently contained to be stable for 7-10 days?
      Answer: Yes.

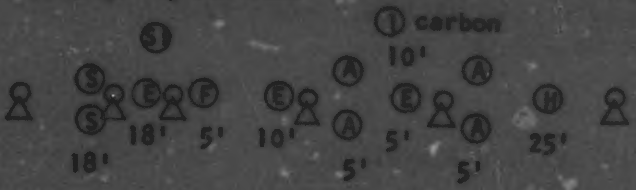
   b. Is their sufficient hauling capacity for 5050 gal. of sludge/day?
      Answer: Yes.

   Evaluation indicates that the sufficient tankage is not avalaible to handle the flow rate. The system must be modified.

XII. Draw an Appropriate Schematic Utilizing the Available Tanks.

Criteria - tanks - 6-5' diameter tanks
4-18' diameter tanks
1-25' diameter tank
2-10' diameter tanks

An 18 foot tank has an effective diameter of 17.5 feet, pumpage is the same



Establish flow through each unit process:
choose the smallest as limiting process flow.

a. sedimentation: $\dfrac{\text{volume available}}{T_T}$

T_T = fill & draw time + settling time

$$V_n = \frac{(17.5)^2 \text{ft}^2 \times 3.14 \times 7.48 \text{ gal.} \times 3 \text{ ft}}{4 \qquad\qquad \text{ft}^3}$$

$$= 5394.7 \text{ gal.}$$

$$T_{fill} = T_{draw} = \frac{5394.7 \text{ gal}}{150 \text{ gpm}} = 36 \text{ min.}$$

SECTION REFERENCE

$$T_T = 2(36 \text{ min}) + 23 \text{ min.}$$
$$= 95 \text{ min.}$$

Volume available = $2 \times V_n$

$$\text{gpm} = \frac{2(5394.7) \text{ gal}}{95 \text{ min.}}$$
$$= 114 \text{ gpm}$$

b. Number of columns (same as filter & carbon).

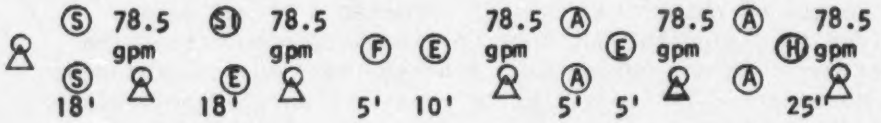
for filters: surface area $= \frac{3.14 \times 5^2 \text{ft}^2}{4}$

$$= 19.6 \text{ ft}^2$$

design = 4gpm/ft^2

$$\text{flow} = \frac{4\text{gpm}}{\text{ft}^2} \times 19.6 \text{ ft}^2$$
$$= 78.5 \text{ gpm}$$

Therefore the operating flow must not exceed 78.5 gpm.



XIII. Compare the Systems

		Optimum System	Actual System
a.	Time to treat	7 days	14 days
b.	Area needed	105' x 85'	82' x 41'
c.	Tanks needed	10-5'D. 5-20'D. 3-25'D 3-10'D	6-5'D tanks 4-18'D 1-25'D 2-10'D
D.	Pumps needed	3 ≥ 150 gpm 3 = 150 gpm 1 - 25 gpm 1 - 50 gpm	3 ≥ 78.5 gpm 3 = 78.5 gpm 1 - 25 gpm 1 - 50 gpm

All other elements are the same.

The responsibility is now up to the OSC to determine if the time factor is more critical to the cleanup operation than the tank shortage. If so, tanks must be made available from any source. If not, the OSC can use available tankage for construction.

SECTION REFERENCE

5.4.5.3 Example: Sodium Cyanide Spill -

Note: All calculations are in English units, the following conversions are appropriate:

lb × 0.454 = kg

ft × 0.305 = m

gal. $\times 3.785 \times 10^{-3}$ = cum

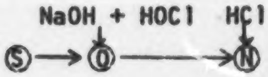
$ft^2 \times 0.093 = m^2$

gpm × 3.784 = lpm

Scene: A truck carrying five 200 lb. drums of 30% sodium cyanide has spilled into a slowly flowing river. A dam has been placed downstream and the upstream water is diverted around the contaminated portion of the stream. Approximately 1,900,000 gallons of water has been contaminated and the bottom of the stream is also affected. It has been decided to dredge the top layer of the bottom and treat the river water in one operation. A presettler and sedimentation are necessary. It is desired to treat the entire spill within 5 days, however only an area 105' x 75' is available for treatment. Establish the most feasible flow system for this situation.

I. Choose Appropriate Flow Scheme

Table 22



Add Na(OH) to pH 8.5 then add HOCl/10% excess/react 1 hour/ neutralize to pH 7 if needed.

II. Do Bench Scale Tests

a. Settling tests: settling tests were done and it was found a presettler was needed. Polyelectrolyte was added at 5 mg/l with a flocculation time of 5 minutes. The settling rate was 0.4 fpm.

b. Oxidation tests indicated that 5 ml of 1N NaOH were needed to raise the pH to 8.5 and 10 ml of 0.05%

SECTION REFERENCE

hypochlorite solution were added per liter of sample. The mixture reacted one hour to degrade cyanide to cyanate and carbon dioxide and nitrogen.

c. Neutralization required only 2 ml of 1N HCl to return the pH to 7.

d. Since no sludge was formed it was established the oxidation and neutralization could occur in the same tank.

e. Sludge volume from the presettler was approximately 4% of the wastewater influent and the height of sludge after sedimentation was 2.0% of the total height.

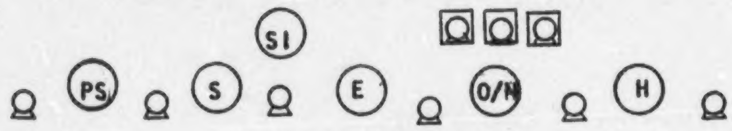
f. Summary of bench test results.

1) presettling - 4% volume of wastewater is sludge.

2) sedimentation - polyelectrolyte dose -
   5 mg / ℓ
   settling rate - 0.4fpm
   sludge volume - 2.0%
   5 minute flocculation time

3) chemical treatment - NaOH - 5ml 1N/ℓ
   HOCl - 10 ml of 0.05%/ℓ
   HCl - 2ml 1N/ℓ

III. Develop an Appropriate Schematic. Figure 41



IV. Calculate Desirable Flow Rate.

$$Q_p = \frac{V_{spill}}{\text{Time to treat}} = \frac{1.9 \times 10^6 \text{ gal.}}{5 \text{ day} \times 16 \frac{\text{hr}}{\text{day}} \times 60 \frac{\text{min}}{\text{hr}}} = 400 \text{ gpm}$$

Explanation: Assume 16 hour per day operation. Use other 8 hours for maintenance, desludging, chemical mixing, etc.

V. Calculate Number of Sedimentation Tanks Required. 6.5.4

SECTION REFERENCE

1. Apply data from settling tests to estimate detention time.

detention time = $\frac{\text{process height}}{\text{settling rate}}$ × 3(safety factor)

parameters: settling rate = 0.4fpm . — 6,5,4
process height, Hp = 3 feet
flocculation time = 5 min.

detention time = $\frac{3\text{ ft.}}{0.4\text{fpm}}$ × 3 = 22.5 min.

Total detention time = 22.5 min + 5 min. = 27.5 min.

2. Calculate fill and draw time. — 6,5,4

Assumption: Pumping rate = 400 gpm (in & out)
tank type = 25' diameter
24' effective dia.
3' process height

tank volume = $V_n = \frac{\Pi D^2}{4}$ Hp × 7.48 $\frac{\text{gal.}}{\text{ft 2}}$

$$= \frac{(3.14) \times (24)^2 \text{ft}^2}{4} \times 3 \text{ ft} \times 7.48 \frac{\text{gal.}}{\text{ft}^3}$$

= 10,146 gal.

$T_{fill} = T_{draw} = \frac{V_n}{\text{pump rate}} = \frac{10,146\text{ gal.}}{400\text{ gpm}}$ = 25.4 min.

T_T = total time = 2(25.4) min. + 28 min. = 78.8 min.

= 79 min.

3. Establish frequency of desludging.

Time between desludging = $\dfrac{0.25 \times Hp \times T_T}{\frac{\text{accumulation of sludge}}{\text{batch}}}$

$\frac{\text{Accumulation of sludge}}{\text{batch}}$ = 0.02 × 3 ft = 0.06 $\frac{\text{ft}}{\text{batch}}$

Time between desludging = $\frac{0.25 \times 3\text{ ft} \times 79\text{ min.}}{0.06\text{ ft/batch}}$ =

= 988 min.

= 16.5 hours

Therefore desludging can occur after operation 16.5 hours.

SECTION REFERENCE

4. Calculate reduction in tank volume caused by sludge accumulation.

$$\text{Amount of sludge accumulated between desludgings} = \frac{\text{amount of sludge}}{\text{batch}} \times \frac{\text{batches}}{\text{before desludging}}$$

Amount of sludge accumulated =

$$0.06 \frac{\text{ft}}{\text{batch}} \times \frac{16 \text{ hr/between desludging}}{79 \text{ min./batch}} \times 60 \text{ min./hour}$$

$$= 0.73 \text{ ft between desludging}$$

Effective process height = Hp - height of sludge accumulated between desludgings.

$$3 \text{ ft} - 0.73 \text{ ft} = H_p \text{ (eff)} = 2.27 \text{ ft}$$

$$V_n \text{ (eff)} = \frac{(24)^2 \text{ft}^2 \times 3.14 \times 2.27 \times 7.48 \text{ gal.}}{4 \text{ ft}^3}$$

$$V_{n(\text{eff})} = 7.677 \text{ gal.}$$

5. Calculate process volume required

$$Vp = Qp \; (T_T)$$

$$= 400 \text{ gpm } (79) \times \text{minutes}$$

$$= 31600 \text{ gal.}$$

6. Calculate the number of tanks needed

$$\frac{Vp}{V_{neff}} = \frac{31600 \text{ gal.}}{7677 \text{ gal/tank}} = 4.1 \text{ tanks}$$

$$= 5 \text{ tanks}$$

VI. Calculate the Number of Oxidation/Neutralization Tanks.

1. Calculate fill and draw time. 6.6.3

Assumptions: pump capacity - 400 gpm
tank diameter - 25'
effective tank diameter - 24'

process height - 3'
tank volume - 10146 gal.

SECTION REFERENCE

2. Fill time = draw time $= \dfrac{Vn}{\text{pump capacity}} = \dfrac{10146 \text{ gal}}{400 \text{ gpm}} = 25.4$ minutes

3. Calculate total detention time

$$T_T = (25.4 \text{ min}) \times 2 + 60 \text{ min for total reaction} = 110.8 \text{ min.}$$

$$= 111 \text{ min.}$$

Explanation: Reaction time is very short for neutralization so the oxidation is the most time consuming.

4. Establish tank volume needed

$$Vp = Qp \quad (T_T)$$

$$= 400 \text{ gpm} \times 111 \text{ min.}$$

$$= 44{,}400 \text{ gal.}$$

5. Calculate number of tanks needed

$$N = \frac{Vp}{Vn}$$

$$= \frac{44{,}400}{10146}$$

$$= 4.4 \text{ tanks}$$

$$= 5 \text{ tanks}$$

Explanation: No sludge accumulates in this process so entire volume is available.

VII. Calculate Number of Sludge Tanks 6.5.4

$$\frac{\text{Volume of sludge}}{\text{day}} = Vp \times 0.04 \times \frac{\text{hour of operation}}{\text{day}}$$

$$= 400 \text{ gpm} \times 0.04 \frac{\text{gal. sludge}}{\text{gal. influent}} \times 16 \text{ hr/day} \times 60 \text{ min./hr.}$$

$$= 15{,}360 \text{ gal./day}$$

SECTION REFERENCE

Assumptions: 25' diameter tank
3' process height
$V_n = 10146$ gal.

$$\text{Number of tanks} = \frac{\text{volume sludge/day}}{\text{volume/tank}} = \frac{15{,}300}{10{,}146}$$

$= 1.5$ tanks

$= 2$ tanks

Explanation: Sludge is removed once per day.

VIII. Estimate Number of Presettling and Equalization Tanks.

1 - presettler - 3000 gal tank is good
1 - equalization - 25' pool, 3' Hp

IX. Calculate Number of Holding Tanks Needed.

Assumption: holding 15 min. of flow
pump into tanks at - 400 gpm
tank volume - 10146 gal.

$$T_T = \text{Total time} = 2\underset{\text{fill \& draw time}}{\left(\frac{10146\ \text{gal}}{400\ \text{gpm}}\right)} + 15\ \text{min.} = 65.7\ \text{min.}$$

$$V_p = Q_p \times T_T$$

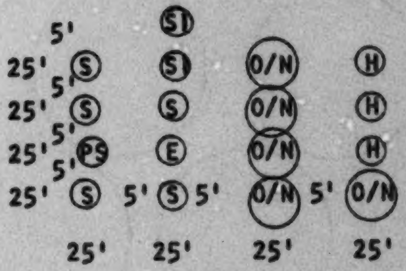
$$= 400\ \text{gpm} \times 65.7\ \text{min.}$$

$$= 26280\ \text{gal.}$$

$$n = \frac{V_p}{V_n} = \frac{26280}{10146}\ \text{gal} = 2.6\ \text{gal./tank}$$

$n = 3$ tanks

X. Revise the Schematic



XI. Evaluate the System. Figure 43

The 1st limiting factor to consider is the space requirement: The system @ 400 gpm requires 115' x 140' and only 105 x 70' is available.

Therefore more consideration is necessary.

XII. Modify the system to comply to limiting factors of the Space Requirement.

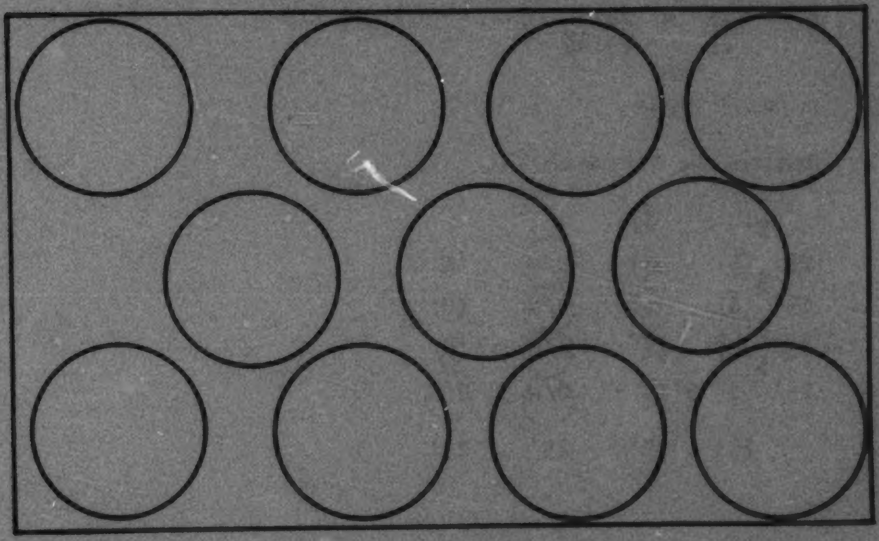
1. Establish available tanks.

3 types are available

D (feet)	calculation	Volume (gal)
18'	(17) ^{2}ft^{2} x 3.14 x 3 ft 7.48/4	5090
20'	(19) ^{2}ft^{2} x 3.14 x 3 ft 7.48/4	6360
25	(24) ^{2}ft^{2} x 3.14 x 3 x 7.48/4	10146

2. See how many tanks fit one area approximately 60 x 100 (accounting for spaces between the tanks).

Trial 1

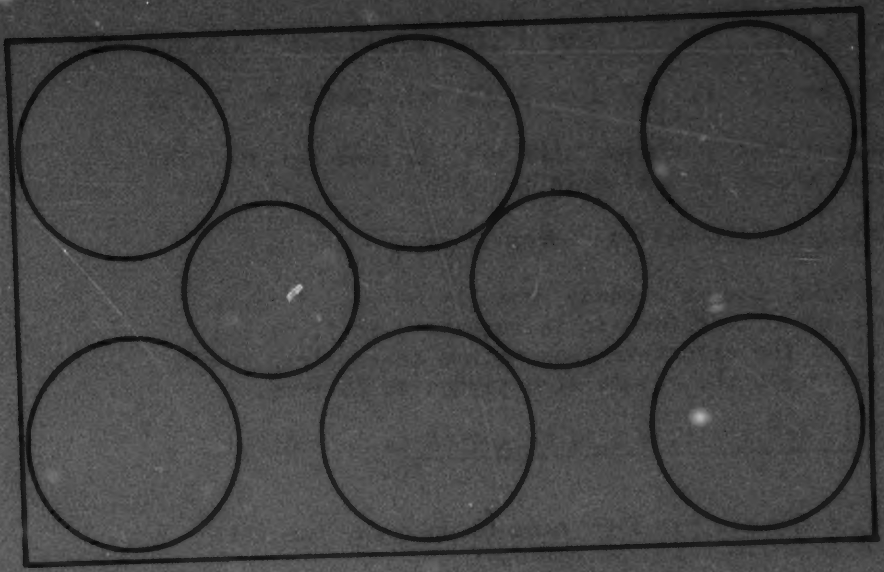


Trial 1 20' D tanks - 11 tanks or 69960 gal.

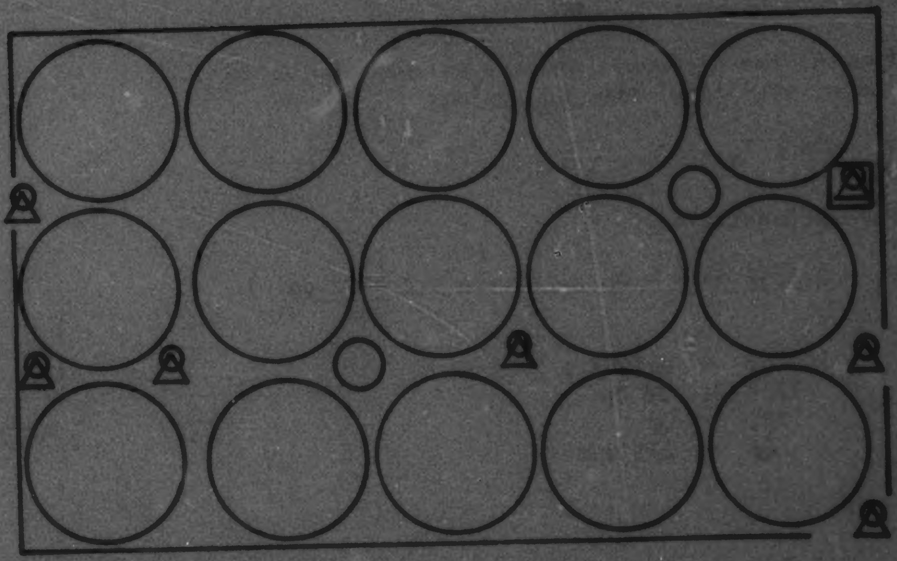
Trial 2 25' D tanks - 6 tanks + 2 20' D = 60876 + 12720 = 73596 gal.

Trial 3 18' D tanks - 15 tanks or 76350 gal.

Trial 2



Trial 3



The usage of tanks could then be calculated based on the following system.

SECTION REFERENCE

3. Estimate the best allocation of tanks to processes.

4. Develop a new flow rate based on a comparison of the two tank total volumes:

System 1 - 17 25' D or 10,146 gal. tanks - 172,482

System 2 - 15 18' D or 5,090 gal. tanks = 76,350

Assume that 5 of the tanks will be used for the O/M step and 4 for sedimentation.

5. Calculate the fill and draw times.

In this case we already know the number of tanks available, therefore it is necessary to first calculate the effective tank volume taking into consideration the accumulated sludge as follows:

$$\frac{(17)^2\,\text{ft}^2 \times 3.14}{4} \times 2.27\ \text{ft} \times \frac{7.48\ \text{gal}}{\text{ft}^3} = 3852\ \text{gal.}$$

Since the process flow rate is unknown, the fill and draw times are as follows:

$$T_T\ \text{sedimentation} = 28\ \text{min} + 2\left(\frac{3852\ \text{gal}}{Qp}\right)$$

$$T_T\ \text{O/M} = 60\ \text{min} + 2\left(\frac{5090\ \text{gal}}{Qp}\right)$$

6. Knowing the allowable process volumes, solve for the process flow rate, Qp using:

$$V_p = Qp \times T_T$$

For sedimentation:

$$V_p = 4(3852\ \text{gal}) = Qp \times \left(28\ \text{min} + 2\ \frac{3852\ \text{gal}}{Qp}\right)$$

$$\begin{aligned} = 15{,}408 &= Qp(28) + 7704 \\ 7704 &= 28\ Qp \\ 275 &= Qp \\ Qp &= 275\ \text{gpm} \end{aligned}$$

For O/R:

$$V_p = 5\ (5090\ \text{gal.}) = Q_p \times \left(60\ \text{min} + \frac{2 \times 5090}{Q_p}\ \text{gal.}\right)$$

$$= 25450 = Q_p \times 60 + 10180$$

$$15270 = 60\ Q_p$$

$$254 = Q_p$$

$$Q_p = 254\ \text{gpm}$$

Therefore the design processes flow rate is the lower of the two, or 254 gpm.

7. The resulting tank utilization would then be:

Number	Type
1	presettler
2	sludge tank
4	sedimentation tank
1	equilization tank
5	oxidation reduction tank
2	holding tanks

XIII. Compare the Two Systems.

Now evaluations of the limiting factors is necessary for both situations.

		Initial Design	Alternate Design
Time limits:		5 days	8 days
Site limits:	location close	yes	yes
	accessible	yes	yes
	clean area	no; need 115' x 140'	yes; 105' x 70'
	flat area	no	yes
	firm area	yes	yes
	setups	OK	OK
	residences	no	no
	vehicular traffic	no	no
Materials:	tanks	17-25' D yes	15-18' D; yes
	pumps	1-20 gpm (solids) 2-10 gpm chem feed	yes; same

	media	not needed	not needed
	chemicals	yes	yes
	spec. equipment	not needed	not needed
Process Restrictions:	settling rate	no problem	no problem
	desludging	no problem	no problem
	contact time	N/A	N/A
	sludge volume	same	same
Manpower Limits:	construction	no	no
	operation	no	no
Miscellaneous:	contaminant	no problem	no problem
	hauling capacity	OK	OK

The choice is then left to the OSC to establish if the time restriction is more critical than the space problem. Possibly more flat area could be cleared for use but the expense and possible time lost may negate the benefits. Each situation must then be evaluated on its own merits.

5.4.5.4 Example: Ammonium Persulfate Spill -

SECTION REFERENCE

Note: All calculations are in English units, the following conversions are appropriate:

$$\text{lb} \times 0.454 = \text{kg}$$

$$\text{ft} \times 0.305 = \text{m}$$

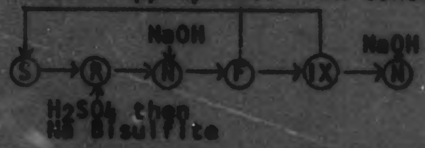
$$\text{gal.} \times 3.785 \times 10^{-3} = \text{cum}$$

$$\text{ft}^2 \times 0.093 = \text{m}^2$$

$$\text{gpm} \times 3.784 = \text{lpm}$$

Scene: A truck carrying six 50 pound packages of ammonium persulfate has spilled into a swamp. The spill is contained but needs treatment within 3 days. The total spill volume is 500,000 gallons of silty swamp water which requires long periods of clarification. However, a limited number of swimming pools and area are available for use. Therefore the OSC must evaluate the situation and choose the best alternative.

1. Choose Appropriate Flow Scheme



Add H_2SO_4 to pH 3/add bisulfite to large ORP change or indicator change/neutralize to pH 7 with NaOH/filter/exchange/neutralize to pH 7 with NaOH — Table 22

SECTION REFERENCE

II. Do Bench Scale Tests 6.5.2

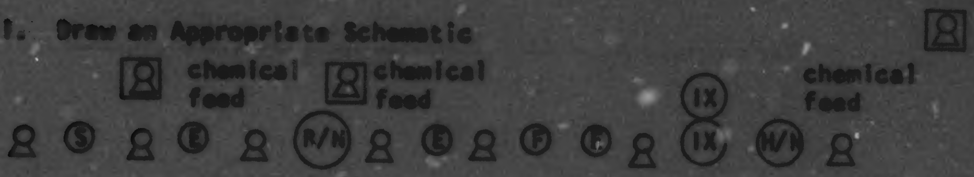
1. Settling tests: A polymer was added in dosages of 25 mg/l and the material was allowed to settle. The settling rate was 0.1 fpm. Flocculation required was 10 min. Sludge accumulation was 1.1 cm.

2. Reduction and neutralization test: 15 ml of 1N H_2SO_4 was added per liter of sample to reach pH of 2 with addition of 10 ml of 100 mg/l sodium bisulfite to the indicator change. (Needs 10 min for reaction.) An additional 10 ml of 1N NaOH returned to pH 7 6.6.7

3. Extra NaOH was ordered to allow readjustment of the pH after ion exchange.

4. Cation analyses were performed to establish need for ion exchange media. Figure 41

III. Draw an Appropriate Schematic



The initial neutralization can be done after reduction is complete in the same tank and the final neutralization can be done in the holding tank.

IV. Calculate Desirable Flow Rate

Assumption: 3 days to clean 500,000 gal. spill

$$\text{flow rate} = \frac{500{,}000 \text{ gal.}}{3 \text{ day} \times 16 \text{ hr/day} \times 60 \text{ hr/min}} = 175 \text{ gpm}$$

Explanation: Use 16 hr/day operation to allow time for maintenance of the system.

V. Establish Number of Sedimentation Tanks Required 6.5.4

1. Apply data from settling test to establish detention time:

$$\text{detention time} = \frac{\text{process height}}{\text{settling rate}} \times 3\ \text{(safety factor)}$$

Assumption: Hp = 3
settling rate = 0.1 fpm

$$\text{Detention time, } t_d = \frac{3\ \text{ft} \times 3}{0.1} = 90\ \text{min}$$

Flocculation time = 10 min

Total detention time = 90 min + 10 min = 100 min.

2. Calculate fill and draw time

Assumption: pumping rate into tank: 175 gpm

tank - 25' dia.
24' effective diameter
3' process height

$$\text{Tank volume } V_n = \frac{3.14 \times (24)^2\ \text{ft}^2}{4} \times 3\ \text{ft} \times \frac{7.48\ \text{gal.}}{\text{ft}^3}$$

$$= 10{,}146$$

$$\text{fill time - draw time} = \frac{V_n}{\text{pumping rate}}$$

$$= \frac{10{,}146\ \text{gal.}}{174\ \text{gpm}} = 58.3\ \text{min}$$

Total time (T_T)=2(58.3) min + 100 min = 216.6 min.

3. Establish Frequency of Desludging

$$\text{Time between desludging} = \frac{0.25 \times \text{Hp}}{\text{accumulation of sludge/batch}} \times T_T$$

Process height = 3 feet

$$\frac{\text{accumulation of sludge}}{\text{batch}} = \frac{1.1\ \text{cm}}{36.6\ \text{cm}} \times 3\ \text{ft} = 0.090\ \text{ft/batch}$$

$$\text{Time between desludging} = \frac{0.25 \times 3\ \text{ft} \times 216.6\ \text{min}}{0.09\ \text{ft}}$$

SECTION REFERENCE

= 1,805 min

= 30.0 hours/between desludging

However, the desludging can be performed after the 16 hours operating period.

4. Calculate reduction in tank volume caused by sludge accumulation

amount of sludge accumulated between desludging =

$$\frac{\text{amt of sludge}}{\text{batch}} \times \frac{\text{batches}}{\text{before desludging}} =$$

$$\frac{0.09 \text{ ft}}{\text{batch}} \times \frac{16 \text{ hours/desludge} \times 60 \text{ min/hr}}{216.6 \text{ min/batch}}$$

= 0.398

approx. 0.4 ft

5. Calculate effective process volume

Hp - height of sludge accumulated = effective process height between desludging

3 ft - 0.4 ft = 2.6 ft

$$\text{Volume tank} = \frac{(3.14)\ (24)^2\ \text{ft}^2}{4} \times 2.6/\text{ft} \times \frac{7.48 \text{ gal.}}{\text{ft}^3}$$

= 8,793.6 gal.

6. Calculate process volume required

$V_p = Q_p\ (T_T)$

= 174 gpm (216.6 min)

= 37,689 gal.

SECTION REFERENCE

7. Calculate number of tanks needed

$$n = \frac{V_p}{V_e}$$

$$= \frac{37,689 \text{ gal.}}{8794 \text{ gal/tank}}$$

$$= 4.3 \text{ tanks}$$

$$n = 5 \text{ tanks}$$

VI. Calculate number of chemical reaction tanks 6.6.9

1. Apply data from bench tests to establish a detention time.

   a. Neutralization - 10 minutes
   b. Reduction - 15 minutes
   c. Safety factor - 5 minutes
   30 minutes

2. Calculate fill and draw rates

   Assumption: 174 gpm influent rate

   Tank specs: 20' diam.
   19' diam.
   3' process height
   6366 gal. process volume

$$\text{fill and draw time} = \frac{V_n}{\text{pump rate}} = \frac{6366 \text{ gal.}}{174 \text{ gpm}} = 36.6 \text{ min.}$$

$$T_T = (36.6)\ 2 \text{ min} + 30 = 103.2 \text{ min.}$$

3. Is desludging necessary? No

   Explanation: The tank is mixed continuously and no sludge is formed. Solids entering the process have been removed in the sedimentation tank.

4. Calculate Required Process Volume

$$V_p = Q_p\ (T_T)$$

SECTION REFERENCE

$$V_p = 174 \text{ gpm } (103.2) \text{ min.}$$

$$= 17{,}957 \text{ gal.}$$

5. Calculate Number of Reaction Tanks Needed

$$N = \frac{V_p}{V_n}$$

$$= \frac{17{,}957 \text{ gal.}}{6366 \text{ gal./tank}}$$

$$= 2.8$$

$$= 3 \text{ tanks}$$

VII. Calculate Number of Filters Needed 6.2.2

Assumptions: 174 gpm flow rate
Loading rate = 4 gpm/ft^2
4' diameter filters

1. Calculate Surface Area of One Filter

$$\text{surface area} = \frac{\pi D^2}{4}$$

$$= \frac{3.14 \times (4)^2 \text{ft}^2}{4}$$

$$= 12.56 \text{ ft}^2$$

2. Calculate Surface Area Needed Based on Flow Rate

$$\text{surface area} = \frac{Q_p}{4 \text{ gpm/ft}^2}$$

$$= \frac{174 \text{ gpm}}{4 \text{ gpm/ft}^2}$$

$$= 43.5 \text{ ft}^2$$

3. Calculate Number of Filters Needed

$$\text{number of filters} = \frac{\text{surface area}}{\text{surface area/filter}}$$

SECTION
REFERENCE

$$= \frac{43.5\ ft^2}{12.56\ ft^2/filter}$$

$$= 3.46\ filters$$

$$= 4\ filters$$

VIII. Calculate Number of Ion Exchange Columns Needed 6.4.2

Assumptions: 174 gpm flow rate
Loading rate - 2 gpm/ft^2
5' diameter columns

1. Calculate Surface Area of One Column

$$\frac{surface\ area}{column} = \frac{\Pi D^2}{4}$$

$$= 19.6\ ft^2/column$$

2. Calculate Surface Area Needed Based on Flow Rate

$$surface\ area\ needed = \frac{Q_p}{2\ gpm/ft^2}$$

$$= \frac{174\ gpm}{2\ gpm/ft^2}$$

$$= 87\ ft^2$$

3. Calculate Number of Columns Needed

$$n = \frac{surface\ area}{surface\ area/column}$$

$$= \frac{87\ ft^2}{19.6\ ft^2/column}$$

$$= 4.4\ columns$$

$$= 5\ columns$$

IX. Design the Holding Tanks

Assumption: 1 hour's flow at 174 gpm (60 min)
24' pool
24' effective diameter
3' process height
10,146 gal. process volume

1. Calculate Fill and Draw Time

$$\text{fill time} = \text{draw time} = \frac{V_n}{\text{flow rate}}$$

$$= \frac{10146 \text{ gal.}}{174 \text{ gpm}}$$

$$= 58.3 \text{ min.}$$

$$T_T = 2(58.3) \text{ min} + 60 \text{ min} = 177 \text{ min}$$

2. Calculate Process Volume

$$V_p = Q_p(T_T)$$

$$= 174 \text{ gpm} \times 177 \text{ min}$$

$$= 30{,}798 \text{ gal.}$$

3. Calculate Number of Tanks

$$n = \frac{V_p}{V_n}$$

$$= \frac{30{,}798 \text{ gal.}}{10{,}146 \text{ gal./tank}}$$

$$= 3 \text{ tanks}$$

X. Design Sludge Holding Tank 6.5.4

Calculate sludge volume for one day of accumulation. The volume to be stored is calculated based on twice the sludge depth due to ineffective draw off techniques

Volume of sludge for storage from 5 sedimentation tanks =

$$\frac{(24)\text{ft}^2 \times 0.8\ \text{ft} \times 3.14 \times 7.48\ \text{gal.} \times 5\ \text{tanks}}{4 \qquad\qquad \text{ft}^3}$$

$$= 13{,}529\ \text{gal.}$$

Assumption: 20' diameter tanks
19' effective diameter
3' process height

$$V_n = \frac{(19)^2\text{ft} \times 3.14 \times 3\ \text{ft} \times 7.48\ \text{gal.}}{4 \qquad\qquad \text{ft}^3}$$

$$= 6360\ \text{gal./tank}$$

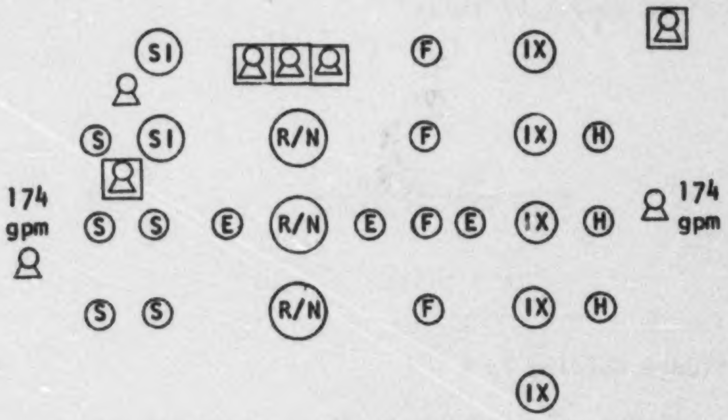
$$\text{number of tanks} = \frac{V_{\text{sludge}}}{V_n} = \frac{13529}{6360}$$

$$= 2.1\ \text{tanks}$$

$$\text{use} = 2\ \text{tanks}$$

Explanation: Store excess sludge in reaction tank after final batch.

XI. Revise the Schematic



SECTION REFERENCE

XII. Evaluate the System

Figure 43

1. Time Limit - The flow is based on time.

2. Site considerations:

   a. Safe proximity?
   Answer: Yes, it is safe to approach and treat.

   b. Accessible?
   Answer: Yes.

   c. Is area clear/flat/firm and available?
   Answer: The area available is not optimal to handle 8-25' dia. pools and 5-20' diameter pools, so a reduction in this area would be desirable.

   d. Proximity to residence?
   Answer: No.

   e. Number of setups required:
   Answer: 1

3. Material Availability

   a. Are enough tanks available?
   Answer: No.

No. Needed	No. Available	Type
8	2	25' diam.
5	3	20' diam.
0	3	18' diam.
3	3	10' diam.
5	5	5' diam.
4	4	4' daim.

   b. Are sufficient pumps available?
   Answer: Yes.

Number	Rates to pump	Available pumps
7	>174 gpm	8 - 250 gpm
1	solids handling	1 - 50 gpm
4	5 gpm chem. feed	4 - 6 gpm chem. feed

c. Is media available?

1) Ion exchange?
Answer: Yes.

2) Chemicals?
Answer: Yes.

3) Special equipment?
Answer: No.

4. Process restrictions?
Answer: None

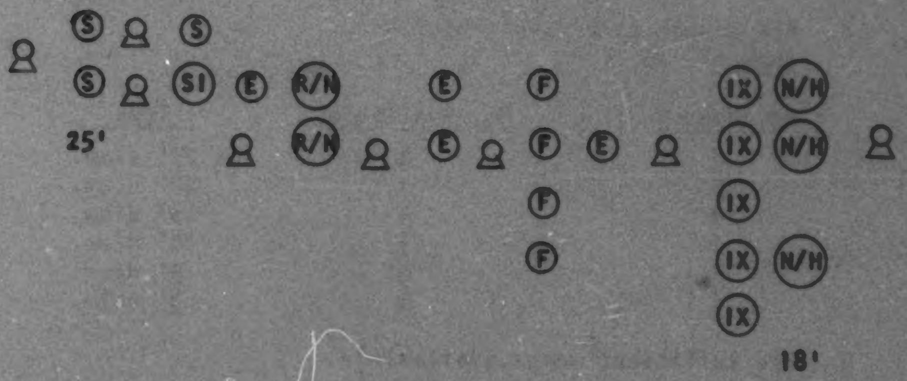
5. Manpower limits?

a. Construction - 10 people available
b. Operation - 25 people available
c. Direction - 3 people available

Therefore, manpower is not critical.

6. Miscellaneous?
Answer: No limits.

XIII. Draw Appropriate Schematic Utilizing Available Tanks and a Smaller Area



XIV. Calculate a New Flow Rate

The effective volume of the sedimentation tanks must be considered first. The sludge accumulates to 0.4 ft

$$V_{eff} = 8794 \text{ gal.}$$

Since the process flow rate is unknown, the total times are calculated as follows.

$$T_T \text{ sedimentation} = 100 + 2 \left(\frac{8794}{Q_p}\right)$$

$$T_T \text{ R/N} = 30 + 2 \left(\frac{6366}{Q_p}\right)$$

$$T_T \text{ N/G} = 10 + 2 \left(\frac{5090}{Q_p}\right)$$

Next the process flow rate is solved for, using the known volume of tankage for sedimentation.

$$V_p = 3\ (8794) = Q_p\ (100 + 2 \left(\frac{8794}{Q_p}\right)$$

$$26{,}382 = 100\ Q_p + 17{,}588$$

$$100\ Q_p = 8{,}794$$

$$Q_p = 87.9 \text{ gpm}$$

For R/N:

$$V_p = 3(6366) = Q_p\ (30 + 2 \left(\frac{6366}{Q_p}\right))$$

$$19{,}098 = 30\ Q_p + 12{,}732$$

$$30\ Q_p = 6366$$

$$Q_p = 212 \text{ gpm}$$

For H/N:

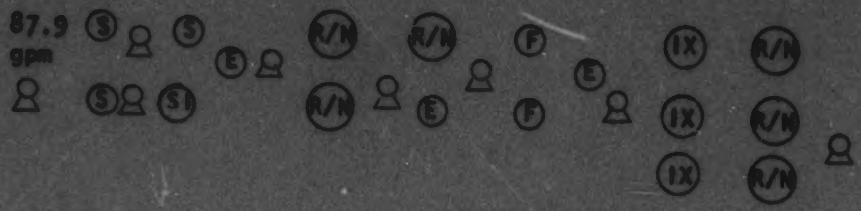
$$V_p = 3\ (5090) = Q_p\ (10 + 2\ \frac{5090}{Q_p})$$

$$15{,}272 = 10\ Q_p + 10{,}180$$

$$10\ Q_p = 5092$$

$$Q_p = 509 \text{ gpm}$$

Note: The limiting 87.9 gpm flow rate is to be evaluated by the OSC. If it is acceptable, the following schematic results are as predicted.


87.9
gpm
S
S
S
SI
E
R/N
R/N
R/N
E
F
F
E
IX
IX
IX
R/N
R/N
R/N

6.0 CHAPTER 6 PROCESS CONSTRUCTION AND OPERATION

6.1 GENERAL

The following subsections detail the information needed for both the design and construction of the various components used in the treatment scheme. This chapter is broken down into 5 parts: filtration, carbon adsorption, ion exchange, gravity separation and chemical reaction. Each of these parts is further subdivided into a process description, bench testing procedures, design considerations, construction details, operation and maintenance and troubleshooting.

It is critical that the user of the Manual be familiar with the format and the content of this subsection. The process description is intended to provide background information to the user and some clarification for assumptions used in the design. Bench testing procedures are outlined for gravity separation and chemical reaction treatment schemes and should be performed on site or at a nearby laboratory on an actual sample of the wastewater to be treated. It will be necessary for the user to be familiar with the techniques and the chemicals presented, prior to actual field operation. The same need occurs with the design and construction section. The directions are indicated as steps with indented cautions, explanations and examples. It is intended that the steps alone can guide the user with reference to the other columns only when necessary. However, previous familiarity to these comments will aid the user in the field.

To use this part of the manual effectively, the user will refer to the portion just following the process description. For column operations, this is entitled: Design of Columns, and for chemical reaction or gravity separation: Bench Testing Procedures. The remainder of the instructions will then follow based on the results obtained.

6.2 FILTRATION

6.2.1 Process Description

Filtration is designed to remove particulate matter by passing contaminated water through a layer of porous media. The applications for this treatment vary from a pretreatment step to provide clarified water to a carbon column or ion exchange system to a polishing step for removal of fine particulates after a precipitation reaction.

Various types of media and modes of operation are used in filtration. However, a simplified mode is needed for field application and therefore a gravity flow dual media column filter has been chosen. The effectiveness of this type of filtration is a function of:

a. The concentration and characteristics of the solids in suspension.

b. The characteristics of the filter media and the mode of operation (media sizes and depths, filtration rate, and terminal head loss).

The filter design presented in this section can provide adequate filtration under a wide variety of solids loading conditions.

Off stream dual media filtration is operated in a column as a gravity downflow process. During a filter run, the process head loss will gradually increase due to accumulation of solids within the filter media. When this head reaches the limit set by the hydraulic conditions of the design, the filter run must be stopped and the filter backwashed. A common fault with filters, especially single media filters, is surface blinding which can shorten the filter run. Dual media filters, utilizing coal above sand, act to give better depth filtration. Backwash involves passing clean process effluent through the filter in a reverse direction and at a rate several times greater than forward flow rate. For downflow gravity filters, the terminal head loss before backwash depends primarily on the available freeboard above the filter media, which is limited by the available tank height. In addition, the effluent quality requirement may control termination of filter runs because effluent quality decreases as the process head loss increases. It is desirable in filter design that acceptable effluent quality be produced within the entire head loss range. Acceptable effluent quality may be dictated by the necessity to efficiently remove contaminated solids from the water stream, or to provide a pretreatment for subsequent processes which would be fouled by solids, such as carbon adsorption or ion exchange.

Filters are usually backwashed with stored filter effluent and backwash wastes are usually retreated and refiltered. Therefore, the total volume treated per filter cycle equals the forward flow volume minus the backwash volume. Generally the higher the solids loading the shorter the filter run and thus the lower the net process flow rate. It is usually easier in the field to set up and operate gravity separation tanks than it is to construct and operate filters. Filter backwash is time consuming, varying from one-half to one hour per filter, and may be manually complicated in systems which must be constructed without the availability of valves or separate backwash pumping systems. In some cases, the filter pump will have to double as a backwash pump, and switch-over from forward to reverse flow will require that hoses be relocated. Personal safety dictates that the number of hose relocations be minimized. Another benefit of extended filter runs is the flexibility it affords in scheduling backwash during process shutdowns or other convenient times.

The filter is a rather difficult process to construct in the field. Thus the mode of dual media filtration outlined in the subsequent design section was scrutinized to simplify field construction and operation as far as is practicable.

6.2.2 Design of Dual Media Filters (43, 44)

1. Determine the required filter area from the process flow rate using Figure 44.

   Explanation: Required filter area is based on a design filtration rate of -

   $$163 \frac{\text{l/min.}}{\text{m}^2} \quad (4\ \text{gpm/ft}^2)$$

   Operational ranges may vary from 80-240 $\frac{\text{l/min.}}{\text{m}^2}$ (2-6 gpm/ft^2)

   Example: (from Figure 44) At 212 l/min, a filter area of 1.31 m^2 will be required.

2. Select a filter tank from Section 7.3 with the following limitations:

   a. A tank with vertical sides (Types A, F, G, K).

   b. An above-ground tank.

   c. A minimum height of 2.7 m (105 in.).

   d. A diameter in the range of 0.61-1.2 m (24-60 in.).

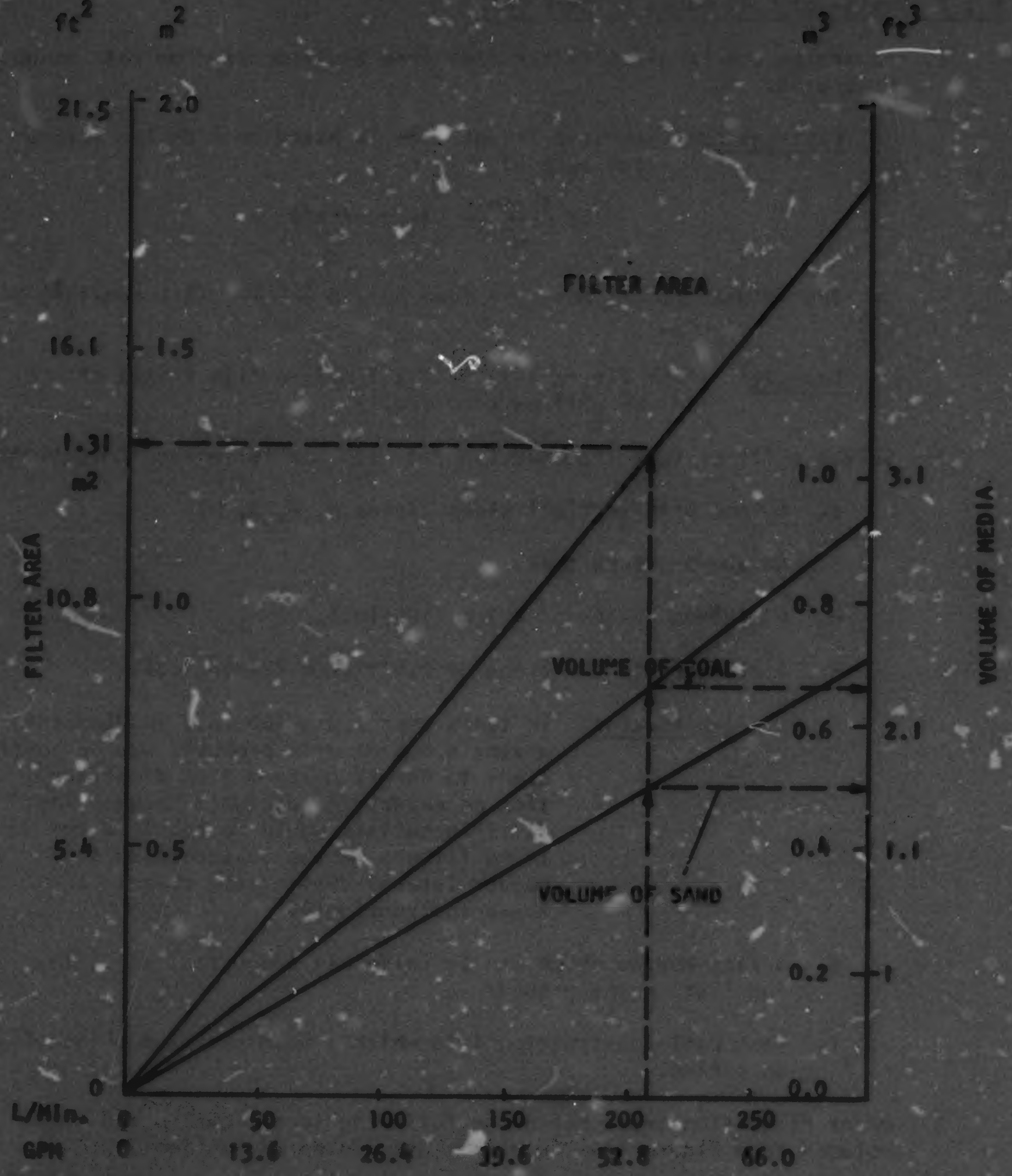
   Explanation: In tanks over 1.2 m (60 in.) in diameter, a single outlet will probably not be sufficient to permit uniform flow distribution necessary for adequate backwashing. Multiple outlets would be required for these filters or the construction of a header lateral system (not covered in these instructions).

   e. A flat bottom which can be uniformly supported, e.g., laying flat on the ground.

   f. Tank wall construction into which a hole may be machined for an outlet.

3. Order filtration media using the following specification and media volumes from Figure 44. Suppliers are listed in Section 7.9

	Silica Sand	Anthracite Coal
Effective size (mm)	0.59-0.60	1.00-1.20
Uniformity Coefficient	1.35-1.70	1.25-1.80



ASSUMPTIONS

1. FILTER AREAS BASED ON HYDRAULIC LOADING OF 163 l/min/sq m (4 gpm/sq ft).
2. 20% EXCESS MEDIA SPECIFIED TO ALLOW FOR SAFETY FACTOR AND SKIMMING.

Figure 44. Filter area and media requirements.

Explanation: The effective size range of anthracite coal listed above is a minimum requirement. If a lower effective size is used, skimming of fines will be required per Section 6.2.4. The lower the uniformity coefficient, the better.

Example: (from Figure 44) For the flow rate of 212 $\frac{\text{l/min.}}{\text{m}^2}$, 0.5 m^3 of sand and 0.66 m^3 of coal will be required.

4. Order gravel for media underdrains from a local sand and gravel yard using amounts from Figure 45. Order equal amounts of pea gravel, and #1 and #2 gravels, and one-half that amount of torpedo sand.

Explanation: Pea gravel is about 0.31 cm (0.23 in.) in diameter; #1 gravel ranges in size from 1.25-1.9 cm (0.5-0.75 in.); #2 gravel ranges in size from 2.50-2.90 cm (1.0-1.5 in.).

Example: (From Figure 45) For the flow rate of 212 l/min., and an underdrain area of 1.31 order the following quantities:

Torpedo Sand - 0.75 m^3,

Pea Gravel, #1 and #2 gravels - 0.55 m^3.

6.2.3 Construction Options for Filters

Preferred option - gravity outlet (Figure 46)

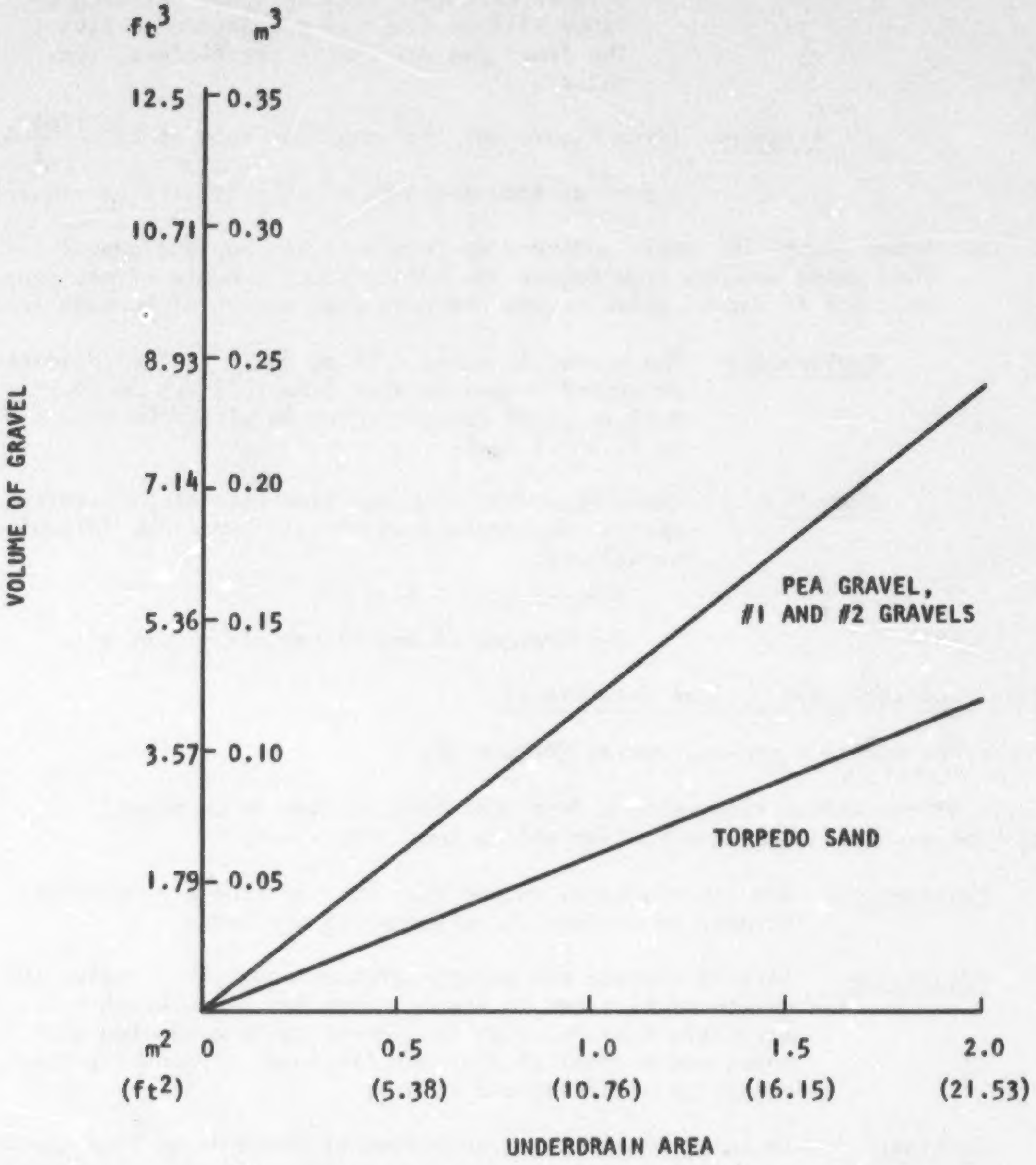
Fully gravitational flow, with a free discharge leading to an equalization tank or a combination equalization and backwash storage tank.

Explanation: Gravity discharge rather than suction from a pump is desirable to prevent air blinding of the bed.

Advantages: Easy to operate and monitor effluent quality. Outlet location permits bed to remain submerged after batch runs, a desirable feature. Can be hydraulically connected with hoses and a total of six hose fittings, eliminating the necessity of piping and valves.

CAUTION: In cases where hazard to personnel would exist from contact with fluid, piping and valves could be installed to eliminate the necessity to transfer hoses when shifting from the forward flow to backwash mode.

Two pumps may be used handling both forward flow and backwash, providing the



ASSUMPTIONS

1. 20% EXCESS SPECIFIED FOR SAFETY FACTOR.

Figure 45. Amounts of underdrain material required for column systems.

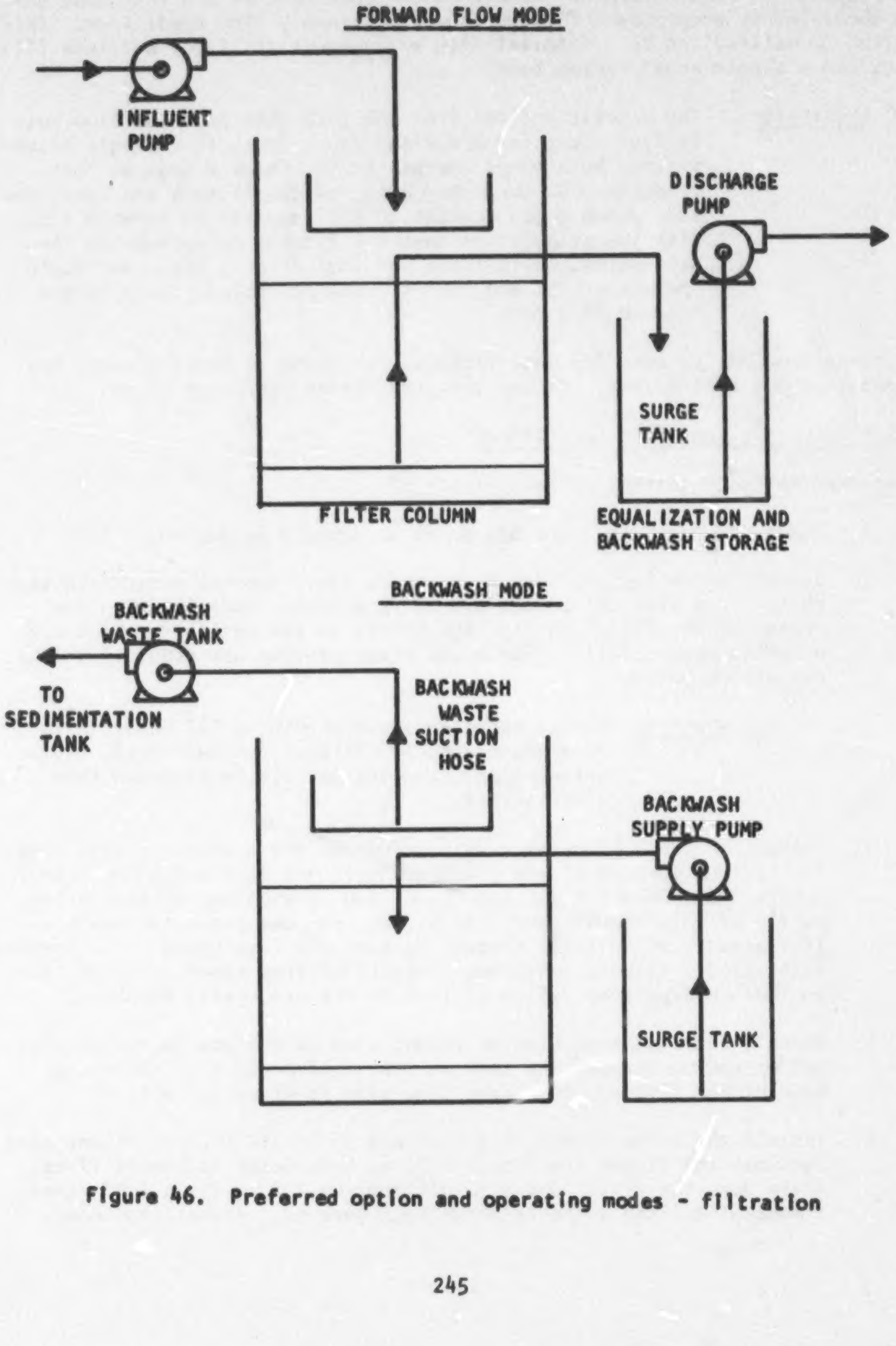

FORWARD FLOW MODE
INFLUENT PUMP
DISCHARGE PUMP
SURGE TANK
FILTER COLUMN
EQUALIZATION AND BACKWASH STORAGE
BACKWASH MODE
BACKWASH WASTE TANK
TO SEDIMENTATION TANK
BACKWASH WASTE SUCTION HOSE
BACKWASH SUPPLY PUMP
SURGE TANK

Figure 46. Preferred option and operating modes - filtration

pump capacities are determined from backwash requirements and that they can be throttled to accommodate forward flow and backwash flow conditions. This option is well-suited to a parallel-flow arrangement utilizing multiple filters and a single equalization tank.

Explanation: The benefit derives from the fact that backwash flow rate is four times forward flow rate. Thus, in a single filter system, both pumps operate in the forward mode at 25% capacity. On the other hand, if two filters are used, the same pumps could operate at 50% capacity in forward flow, with the stipulation that the filters be backwashed individually. With three and four filters the pumps would operate at 75% and 100% of capacity respectively in the forward flow mode.

Any type tank may be used for equalization, in-ground or above ground, provided that the wall height be lower than the filter discharge height.

6.2.4 Construction Steps for Filters

Preferred Option - gravity outlet (Figure 47)

1. Construct tank shell and bottom as instructed in Section 7.3.3.

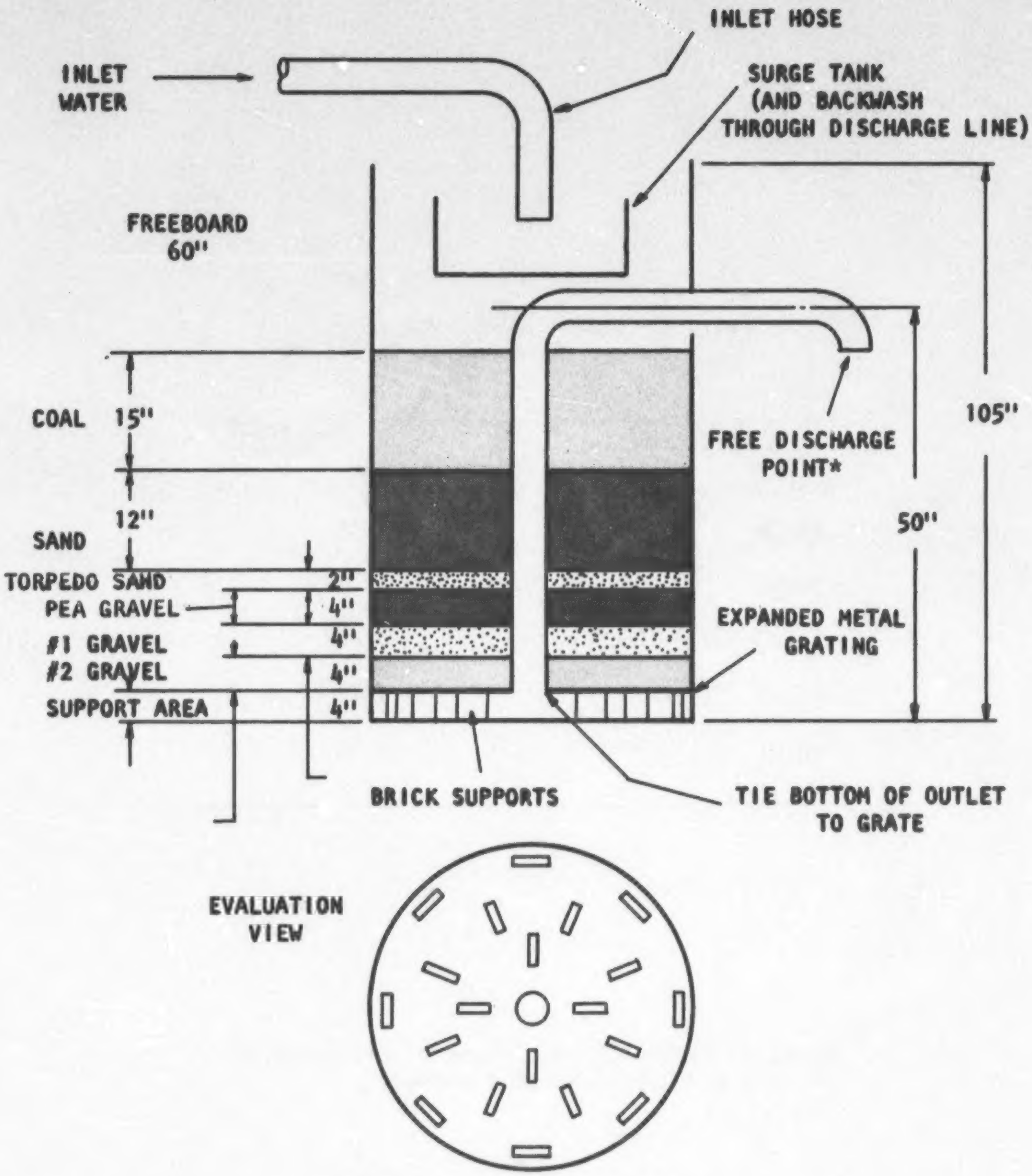
2. Install brick supports for an expanded metal grating underdrain support. Note that all bricks are to be oriented radially with the center of the filter, except the bricks on the periphery which are oriented tangentially. For a one piece grating use about 12 bricks per square meter.

   Explanation: During backwash the distribution of water in the underdrain area is critical. Symmetrical, radial orientation of bricks assists in backwash flow distribution.

3. Install an expanded metal grating covering the complete filter area. The maximum opening in the grating should not pass a 2.5 cm (1 in.) sphere. Standard 3.0 lb, 4.0 lb, or 5.0 lb expanded metal grating will meet this requirement. Construct from one piece if possible. If installed in multiple pieces, be sure the free edges are supported sufficiently (almost continuous support of free edge). Fit grating so that no gaps over 2.5 cm (1 in.) in diameter exist anywhere.

4. Install the discharge line as shown, tied on one end to the grating and extending through the tank wall at 1.27 m (50 in.) above the base of the filter. Discharge line size is given in Table 25.

5. Install the three layers of gravel and 33 cm (13 in.) of filter sand. Backwash the filter (Section 6.2.5) at this point to remove fines; drain down the filter and skim off the top 2.5 cm (1 in.) of fines. A makeshift fines scoop is shown in Figure 48. Install the coal,


INLET HOSE
INLET WATER
SURGE TANK (AND BACKWASH THROUGH DISCHARGE LINE)
FREEBOARD 60"
105"
COAL 15"
FREE DISCHARGE POINT*
12"
SAND
50"
TORPEDO SAND 2"
PEA GRAVEL 4"
#1 GRAVEL 4"
#2 GRAVEL 4"
SUPPORT AREA 4"
EXPANDED METAL GRATING
BRICK SUPPORTS
TIE BOTTOM OF OUTLET TO GRATE
EVALUATION VIEW

PLAN FOR PLACEMENT OF BRICKS

* DO NOT LET THE FREE DISCHARGE POINT EXTEND BELOW THE TOP OF THE BED
INCHES x 2.54 = cm

Figure 47. Construction details for filters.

Table 25. COLUMN OPERATION DISCHARGE LINE SIZING [1]

Maximum Flow		Line Size	
l/min.	GPM	cm	in.
11.36	3	2.54	1
37.85	10	3.81	1.5
83.27	22	5.08	2
189.25	50	7.62	3
340.65	90	10.16	4

---

[1] Based on maximum total length of discharge of 10 feet and head loss of 2 inches.

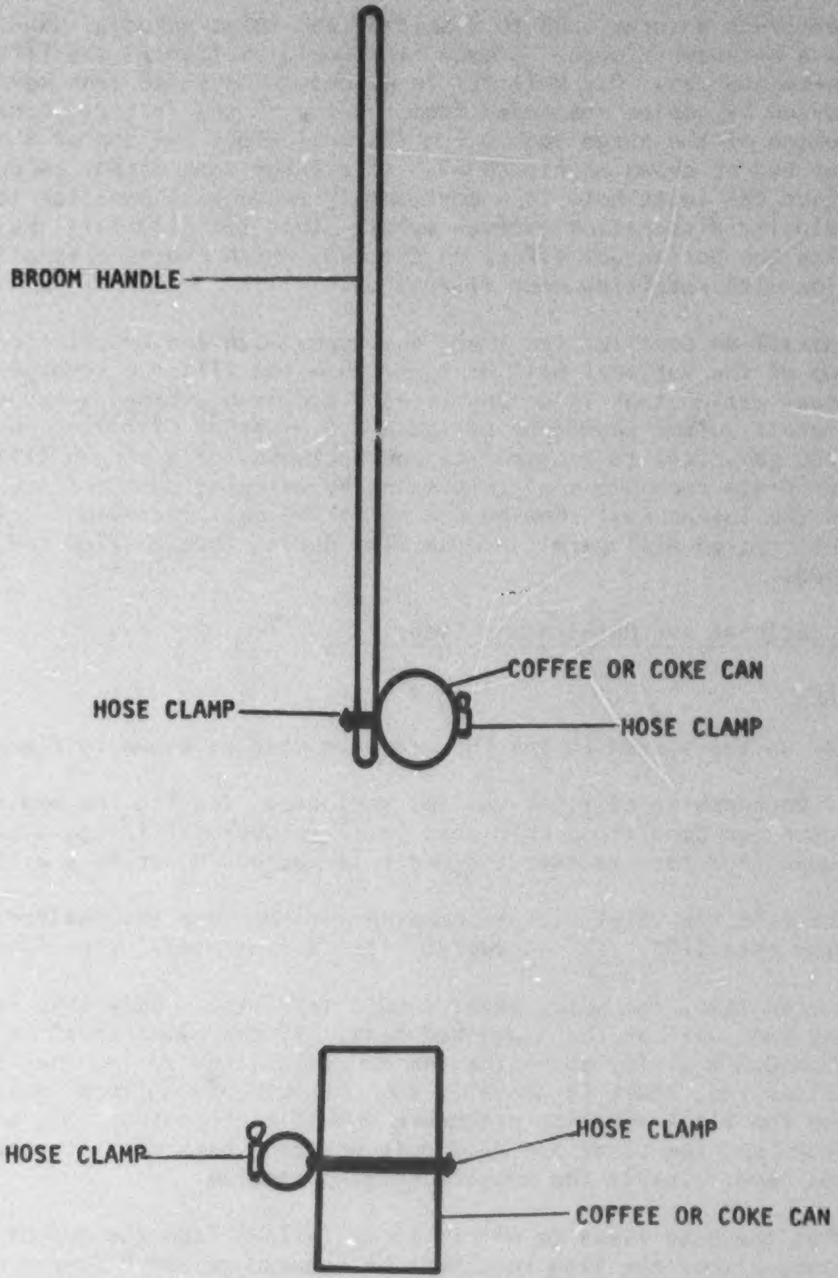

BROOM HANDLE
COFFEE OR COKE CAN
HOSE CLAMP
HOSE CLAMP
HOSE CLAMP
HOSE CLAMP
COFFEE OR COKE CAN

Figure 48. Fines scoop.

backwash again, and remove 2.5 cm (1 in.) of coal fines.

6. Construct a surge tank to dissipate the inlet velocity head and act as a backwash trough. A good size would be 1/4-1/3 the filter diameter and about 0.3 m (1 ft) in height. The surge tank may be supported by cables suspended from the top of the filter. Locate the bottom of the surge tank 0.6 m (24 in.) above the top of the filter bed as shown on Figure 47. If a surge tank cannot be constructed, place the inlet hose in a horizontal, tangential position to cause velocity dissipation through swirl. This technique will help minimize the boring out effect on the bed, which causes channeling of flow with resulting poor filtration.

7. Install an equalization tank, any type, with the restriction that the top of the vertical wall be lower than the filter discharge. If the equalization tank is to double as a backwash storage tank, the process volume should be at least 8.0 m^3 per m^2 of filter bed (200 gal./ft^2) to accommodate one backwash for a single filter. Calibrate the volume of this tank, by calculations, and put a scale on the inside wall showing 0.4 m^3 or 100 gal. increments. This calibration will permit proper flow during forward flow and backwash modes.

6.2.5 Operational and Maintenance Steps

Forward Flow-

1. Set up the system in the forward flow mode as shown in Figure 46.

2. If backwashing of fines was not performed, leaving the media in submerged condition, care must be taken during filling, e.g., reduced flow rate so that the media is not bored out by the flow.

3. Throttle the inlet flow as necessary to achieve the desired filtration rate (163 $\frac{\text{l/min.}}{\text{sq m}}$ (4 gpm/ft^2) is design rate). When flowing at design rate, the water level should stabilize. Mark this level on the tank wall as the clean bed head. If the water level is more than 0.3 m (1 ft) above the bed at design flow during the first filter run, there is probably some blinding from fines taking place and the fines removing procedure should be repeated. If, after backwash, the clear bed head does not come back close to the clean bed head, consult the troubleshooting section.

4. When the head rises to within 15 cm (6 in.) from the top of the tank, either the flow rate must be reduced or the filter must be backwashed.

Backwash Mode (44)-

1. Set up the system for the backwash mode as shown in Figure 49. Restrain the backwash waste suction hose so that it will not be possible for it to become attached to the bottom of the surge tank. This would starve the backwash waste pump and require that it be shut off momentarily to release the hose.

   Explanation: Backwashing of filters is intended to:

   a. Remove undesirable fines during filter preparation.
   b. Remove collected suspended materials.
   c. Stratify the bed.
   d. Remove air bubbles and pockets.

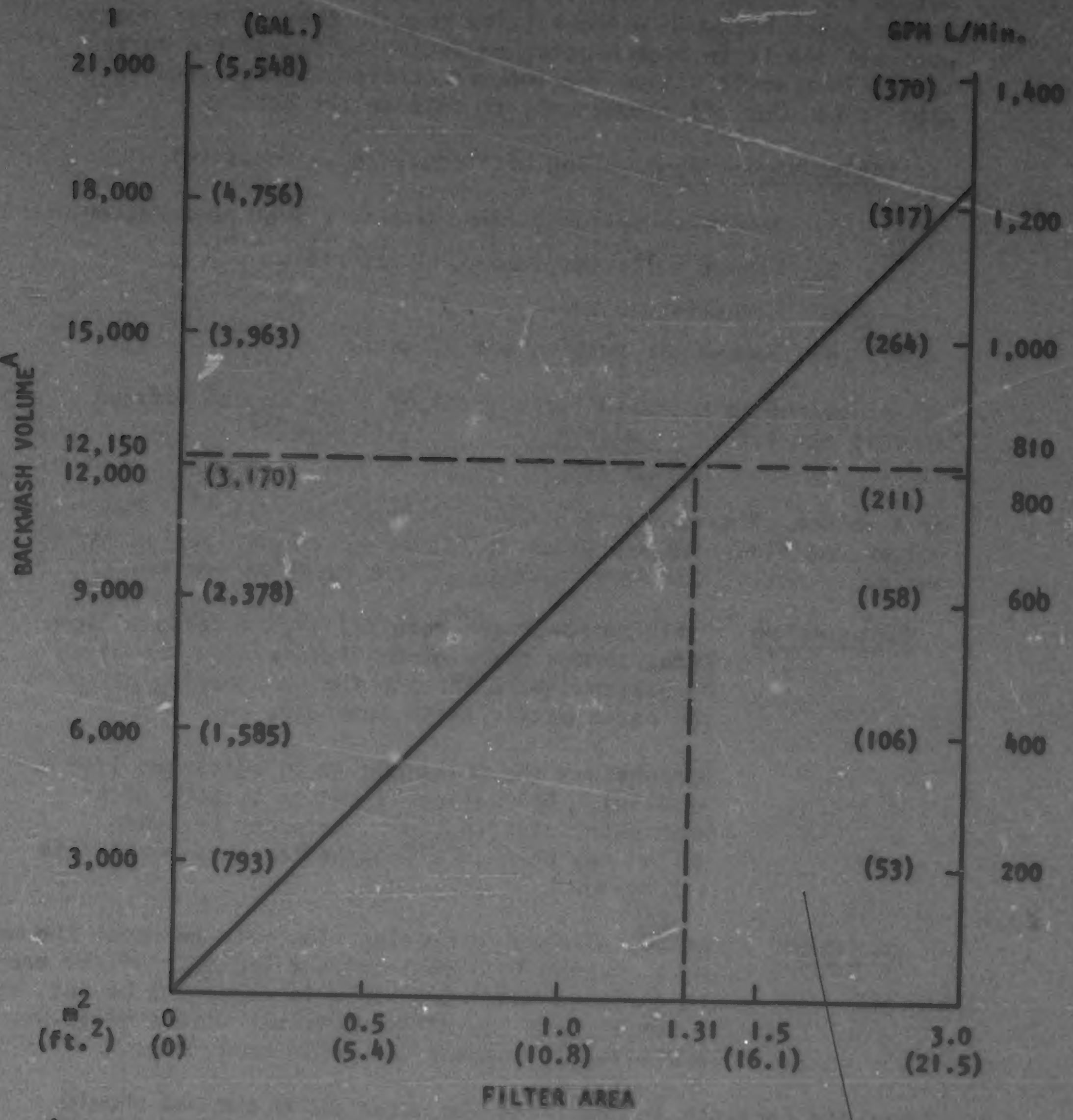
2. It is desired to backwash for a total of about ten to fifteen minutes at: $4.1 \ \frac{m^3/min}{m^2 \text{ of filter}}$ (10 gpm/ft^2), or a volume of about 41-61.5 m^3/m^2 (100-150 gal./ft.^{2}). The required volume and flow rate are given in Figure 49. Flow setting may be easier by noting the drop in level of the equalization tank.

   Explanation: Efficient backwash requires that a certain flow rate, termed the minimum fluidization velocity, be passed upward through the bed causing all of the media particles to separate.

   Note whether the total bed is in agitation (desirable). Channeling is caused by poor backwash water distribution. Extended backwash period may help to effect better removal in this situation.

   CAUTION: Do not allow an excessive flow rate to cause the media to be washed into the effluent trough. If you are in doubt as to whether this is happening or not, take a sample near the effluent trough with a glass jar and visually inspect for media carry-over.

3. After the backwash is completed the water above the bed should appear to be clear and not murky. After the pump is turned off, a short duration must be allowed for the water to syphon backward through the backwash pump thus permitting the hose connection at the filter discharge to be separated without having a back pressure behind it.



^A VOLUME BASED ON 15 MIN. BACKWASH

^B FLOW RATE BASED ON 611 $\frac{\text{l/min.}}{m^2}$

Figure 49. Backwash volumes for column processes.

6.2.6 Filter Troubleshooting

1. Mudballing - In cases where a silty water is being filtered or oils or greases are present, mud balls may form and gradually pass downward through the bed during backwash. They tend to accumulate at the media support and act to restrict flow. Mudballing may be alleviated by air lancing. An air compressor of 0.28cu m/min. (10 cfm) capacity is connected to a straight 1.2 cm (0.5") tube. A valve is necessary to meter the flow of air through the tube. The tube should be inserted into the bed no further than the torpedo sand layer 68.5 cm (27"). The bed must be covered with water during air lancing but the backwash pump must be left off. The tube is moved around to cover the entire bed area. The air discharge should cause significant local turbulence. After the air lancing procedure is completed, the bed must be backwashed before being put back in operation.

2. Excessive Clean Bed Head - If backwashing and/or air lancing does not permit return to the clean bed head, 2-5 cm (1-2 in.) of coal may be removed and replaced. This procedure will be especially effective if surface blinding is occurring.

3. Poor Effluent Quality - Suggests:
   a. Too high a flow rate.
   b. Poor filterability of the process flow.
   c. Channeling of the bed (uneven distribution of flow)
   d. Excessive intermixing of the media.

6.3 CARBON ADSORPTION

6.3.1 Process Description

Activated carbon adsorption is a physical phenomenon which removes organic and some inorganic chemicals from water. These chemicals are physically adsorbed on the large surface area of the carbon (typically 500-1000 m^2/gr). The activated carbon can be produced from various cellulosic materials including wood, coal, peat, lignin, etc. These are prepared using dehydration and carbonization, followed by activation to enlarge the pore openings, which increases the surface area and therefore increases the adsorptive capacity.

The adsorption process is dependent on the nature of the material being adsorbed, the solution and the carbon used for adsorption. Critical factors include molecular size and polarity, type of carbon, pH of the solution, carbon contact time and solubility of the contaminant. The adsorption rate increases with increasing temperature and decreasing concentrations. In general, concentrations greater than 1000 mg/l of soluble contaminant require excessive detention times and produce large amounts of spent carbon.

The amount of carbon needed to adsorb a certain chemical must be established by actual testing. Various tests can be used, but these should be done on the contaminant in its natural environment since constituents of the medium may also exert a carbon "demand". One test which can be run is a carbon isotherm. This test indicates the amount of contaminant adsorbed per weight of carbon at equilibrium conditions. However, since equilibrium conditions are not met in the actual application, scale-up factors are required. Other shorter tests compare adsorption of molecules on different types of carbon. The Molasses number indicates a carbon's affinity for large molecules and a Iodine number the affinity for small molecules (45). More information on these tests is available in other sources (46).

Once the capacity of the carbon has been reached, the carbon must be replaced and the spent carbon disposed of or regenerated for reuse. Regeneration can be done using various physical and chemical techniques. However, thermal regeneration is the most common method. This process requires high temperatures and a controlled atmosphere and is therefore unsuited for field implementation unless a preconstructed mobile system is available. Instead, carbon should be removed and hauled to an established site for regeneration or incineration.

Offstream treatment is typically done using either powdered or granular carbon. Usually offstream treatment is performed in column tanks which provide efficient use of the carbon in the system. Carbon columns are similar to filters in many ways:

1. Efficiency of the bed is dependant on good flow distribution which will provide uniform contact time for the entire fluid stream.

2. An underdrain system is necessary to prevent the carbon from exiting with the effluent water and to distribute backwash water.

3. Initial backwash is required to remove fines and air pockets, as well as to stratify the bed.

In other ways, carbon columns are distinct from filter operations:

1. Termination of the cycle is established by "breakthrough" which indicates that the adsorptive capacity of the bed has been reached. Once spent, the carbon must be transported out of the bed and replaced with fresh media.

2. For efficient adsorption, the carbon must be "wetted" prior to use. This process may require up to 24 hours at room temperature with the carbon submerged in clean water (or less time at higher temperatures). Therefore, a source of clean water must be available on site for use in wetting the carbon prior to startup of the system.

3. Use of the carbon column as a filter causes inefficient use of the adsorption capabilities. Therefore, clarification processes including dual media filtration are necessary pretreatment steps prior to carbon adsorption.

4. Carbon columns possess more versatility than filters and can be operated in either downflow or upflow modes. Suspended solids are not removed during upflow operation due to bed expansion and extra contact time is generally necessary for this operation because of the expanded bed condition.

When a carbon adsorption process is constructed in the field, the first, priority is the ordering of carbon which may require a 24 to 48 hour lead time and an additional 24 hours to wet prior to use. The amount of carbon required is determined by the treatment specifications in Table 22. A range of weight of carbon per weight of soluble contaminant is given to aid in ordering the carbon. The following calculation should be done to determine the amount of carbon needed.

Example A.

1. Spill of Parathion: 10^5 gal. of water
   The solubility of Parathion is 24 mg/l
   Pounds of soluble Parathion = $\frac{24 \times 8.34 \times 10^5}{10^6}$ = 20.0 lbs
   (lbs x .454 = kg)
   (gal. x 3.785 = l)
   Then, the range of carbon needed to remove parathion is 100-300 #/# of soluble material. Therefore, the maximum number of pounds of carbon is 20.0 lbs. of parathion x 300 = 6,000 lbs. of carbon. This amount should be ordered.

Once the carbon is placed in the column, then the actual carbon requirement of the system must be tested. Since it is recommended that the carbon columns be run in series with an equalization tank between, samples can be taken periodically from the effluent lines of the columns, composited, and sent the laboratory for analysis. These analyses will indicate when the first carbon column has broken through and future carbon changes can be based on that time period or additional sampling. The second column will allow the operation to safely continue in the interim until the samples can be analyzed.

When using powdered carbon during offstream operation, carbon can be injected into a tank, mixed via hydraulic, air or mechanical means and then collected prior to discharge of the wastewater. However, the carbon is not used as efficiently with this method, but the same weight of carbon should be initially ordered. As the carbon is spent, the data can be extrapolated and the additional amount ordered.

6.3.2 Design of Activated Carbon Columns (46, 47)

1. Order the activated carbon using the formula presented in the process description to determine the total amount of activated carbon required to treat the spill.

   CAUTION: Due to the long times required to get the activated carbon on site, it is essential that it be ordered immediately! If the total amount can not be obtained at once, have the available weight shipped immediately.

2. Wet the activated carbon.

   Explanation: The activated carbon should be deposited in holding tanks and sufficient water should be added to cover the carbon with 6" or more of water.

   CAUTION : This step is essential for good removal rates during operation of the activated carbon column.

3. Determine the required activated carbon bed surface area from the process flow rate using Figure 50.

   Explanation: Required carbon bed surface area is based on a design bed flow rate of

$$81.4\ \frac{\text{l/min}}{\text{m}^2} = 2.0\ \text{gpm/ft}^2$$

   Operational ranges may vary from

$$40.7\text{-}81.4\ \frac{\text{l/min}}{\text{m}^2}\quad (1\text{-}2\ \text{gpm/ft}^2)$$

   Example: (From Figure 50) At 212 l/min, a bed area of 2.60 m^2 will be required.

4. Select a carbon column tank from Section 7.3 with the following:

   a. A tank with vertical sides (Types A, F, G).

   b. An above-ground tank.

   c. A minimum height of 2.7 m (105 in).

   d. A diameter in the range of .6-1.2 m (24-60 in).

      Explanation: Over 1.2 m (60 in.) in diameter, a single outlet will probably not be sufficient to permit uniform flow distribution necessary for adequate backwashing. Multiple outlets would be required for these larger sizes or the construction of a header lateral system (not covered in these instructions).

   e. A flat bottom which can be uniformly supported, e.g., laying flat on the ground.

   f. Tank wall construction which a hole may be machined for an outlet.

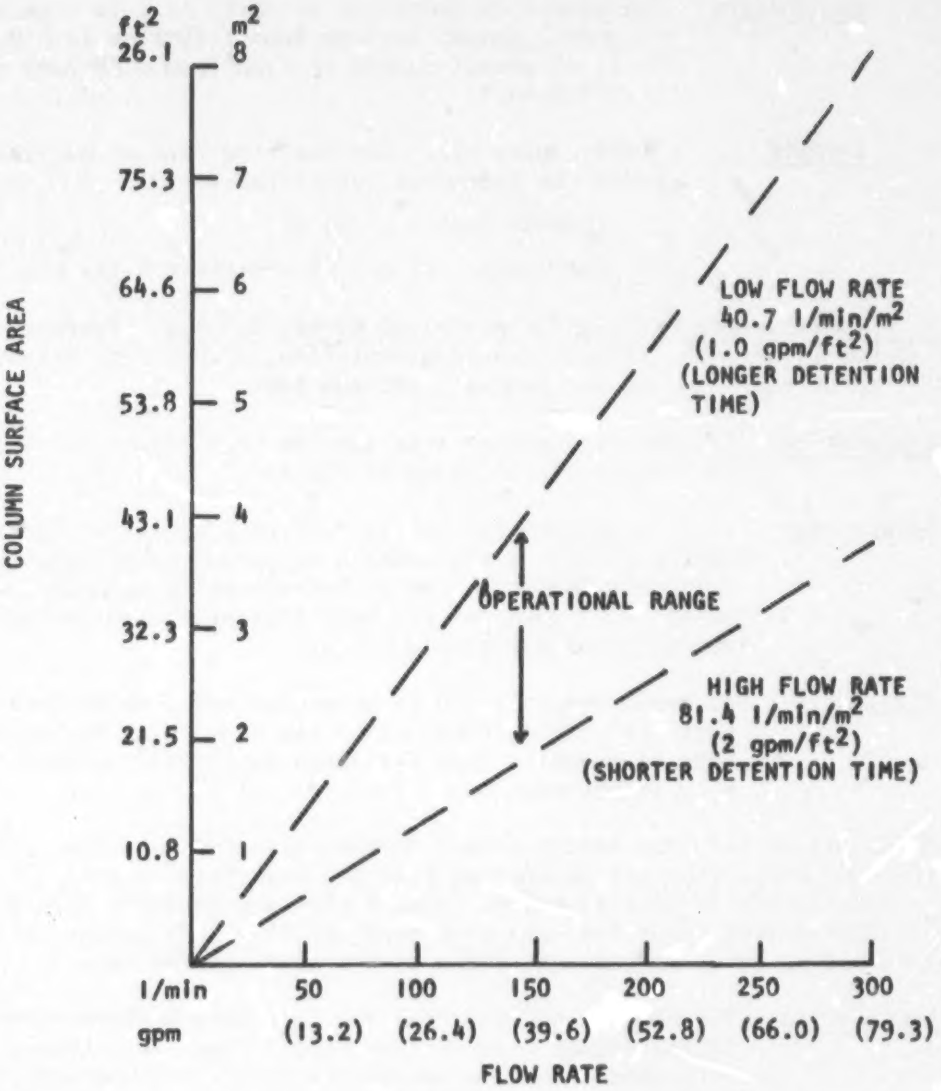


Figure 50. Required surface area for carbon columns.

5. Order gravel for media underdrains from a local sand and gravel yard using amounts from Figure 45. Order equal amounts of pea gravel, and #1 and #2 gravels, and one-half that amount of torpedo sand.

   Explanation: Pea gravel is about .31 cm (0.23 in.) in diameter; #1 gravel ranges in size from 1.25-1 cm (0.5-0.75 in.); #2 gravel ranges in size from 2.50-2.90 cm (1.0-1.5 in.).

   Example: (From Figure 45). For the flow rate of 212 l/min, order the following quantities;

   Torpedo Sand - 0.065 m^3

   Pea Gravel, #1 and #2 gravels - 0.132 m^3,

6.3.3 Construction Options for Activated Carbon Columns - Preferred option Gravity Outlet (Figure 51) Full gravitational flow, with a free discharge leading to an equalization and backwash storage tank.

Explanation: Gravity flow rather than suction from a pump is desirable to prevent air blinding of the bed.

Advantages: Easy to operate and monitor effluent quality. Outlet location permits bed to remain submerged after batch runs, a desirable feature. Can be hydraulically connected with hoses and a total of six hose fittings; eliminating the necessity of piping and valves.

CAUTION: In cases where hazard to personnel would exist from contact with fluid, this option has a drawback in the necessity to manually transfer hoses when shifting the forward flow to backwash mode.

Two pumps may be used for handling both forward flow and backwash, providing the pump capacities are determined from backwash requirements and that they can be throttled to accommodate forward flow and backwash flow conditions. This option is well-suited to a parallel flow arrangement utilizing multiple activated carbon columns and a single equalization tank.

Explanation: The benefit derives from the fact that backwash flow rate is four times forward flow rate. Thus, in a single activated carbon column system both pumps operate in the forward mode at 25% capacity. On the other hand, if say two activated carbon columns are used, the pump could operate at 50% capacity in forward flow, with the stipulation that the activated carbon columns be backwashed individually.

Any type tank may be used for equalization, in-ground or out, provided that the wall height be lower than the activated carbon column outlet fitting height.

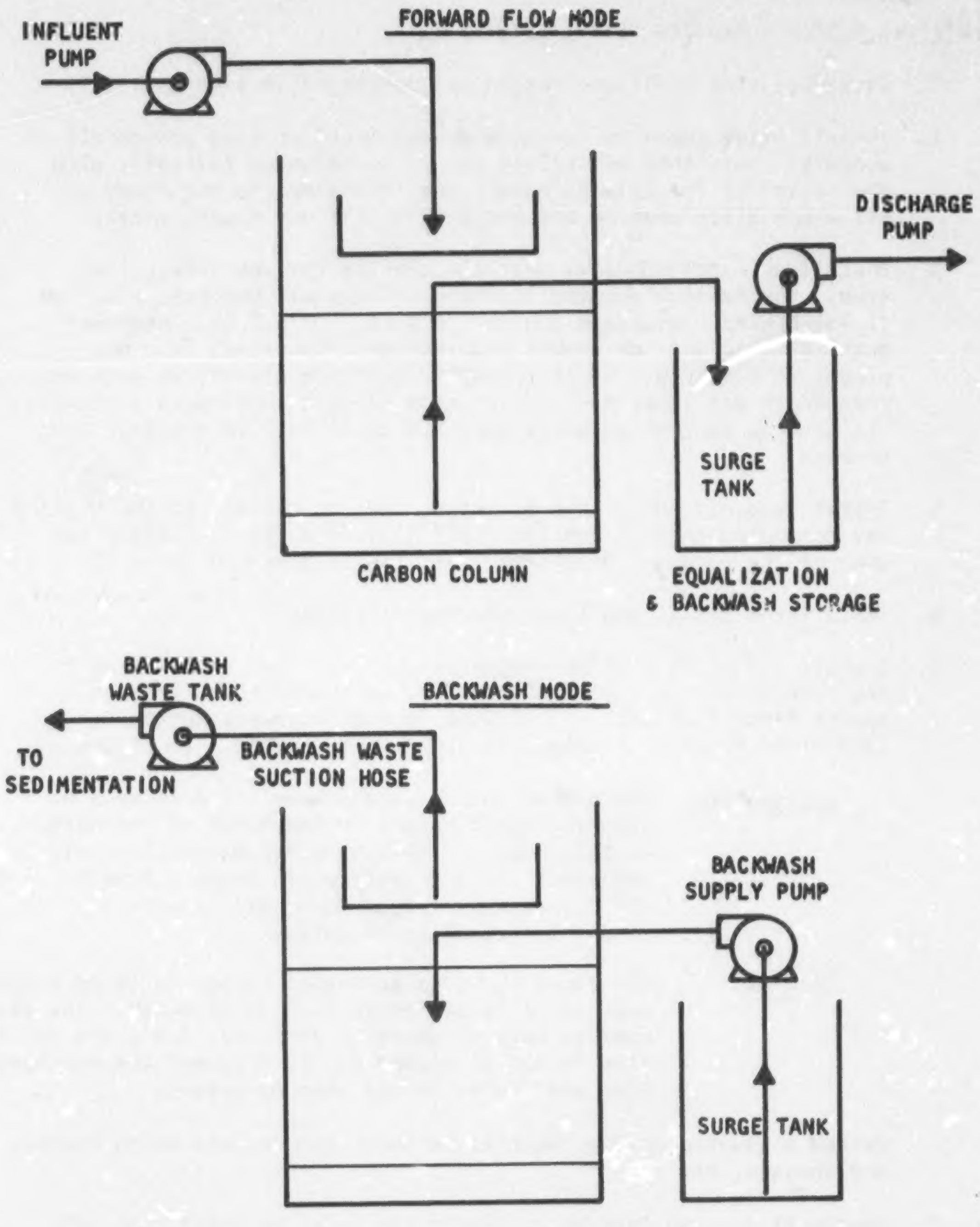

FORWARD FLOW MODE
INFLUENT PUMP
DISCHARGE PUMP
SURGE TANK
CARBON COLUMN
EQUALIZATION & BACKWASH STORAGE
BACKWASH WASTE TANK
BACKWASH MODE
TO SEDIMENTATION
BACKWASH WASTE SUCTION HOSE
BACKWASH SUPPLY PUMP
SURGE TANK

Figure 51. Preferred option and operating modes - carbon adsorption

6.3.4 Construction Steps for Activated Carbon Columns

Preferred Option - Gravity Outlet (Figure 52).

1. Construct tank shell and bottom as instructed in Section 7.3.3.

2. Install brick supports for an expanded metal grating underdrain support. Note that all bricks are to be oriented radically with the center of the column, except the bricks on the periphery. For a one piece grating use about 12 bricks per square meter.

3. Install an expanded metal grating covering the complete column area. The maximum opening in the grating shall not pass a 2.5 cm (1 in) sphere. Standard 3.0 lb., 4.0 lb., or 5.0 lb., expanded metal grating will meet this requirement. Construct from one piece, if possible. If installed in multiple pieces, be sure the free edges are supported sufficiently (almost continuous support). Fit grating so that no holes over 2.5 cm (1 in.) in diameter are created.

4. Install the discharge line as shown, tied on one end to the grating and extending through the tank wall at 1.27 m (50 in.) above the base of the column. Discharge line size is given in Table 25.

5. Install the gravel and sand underdrain layers.

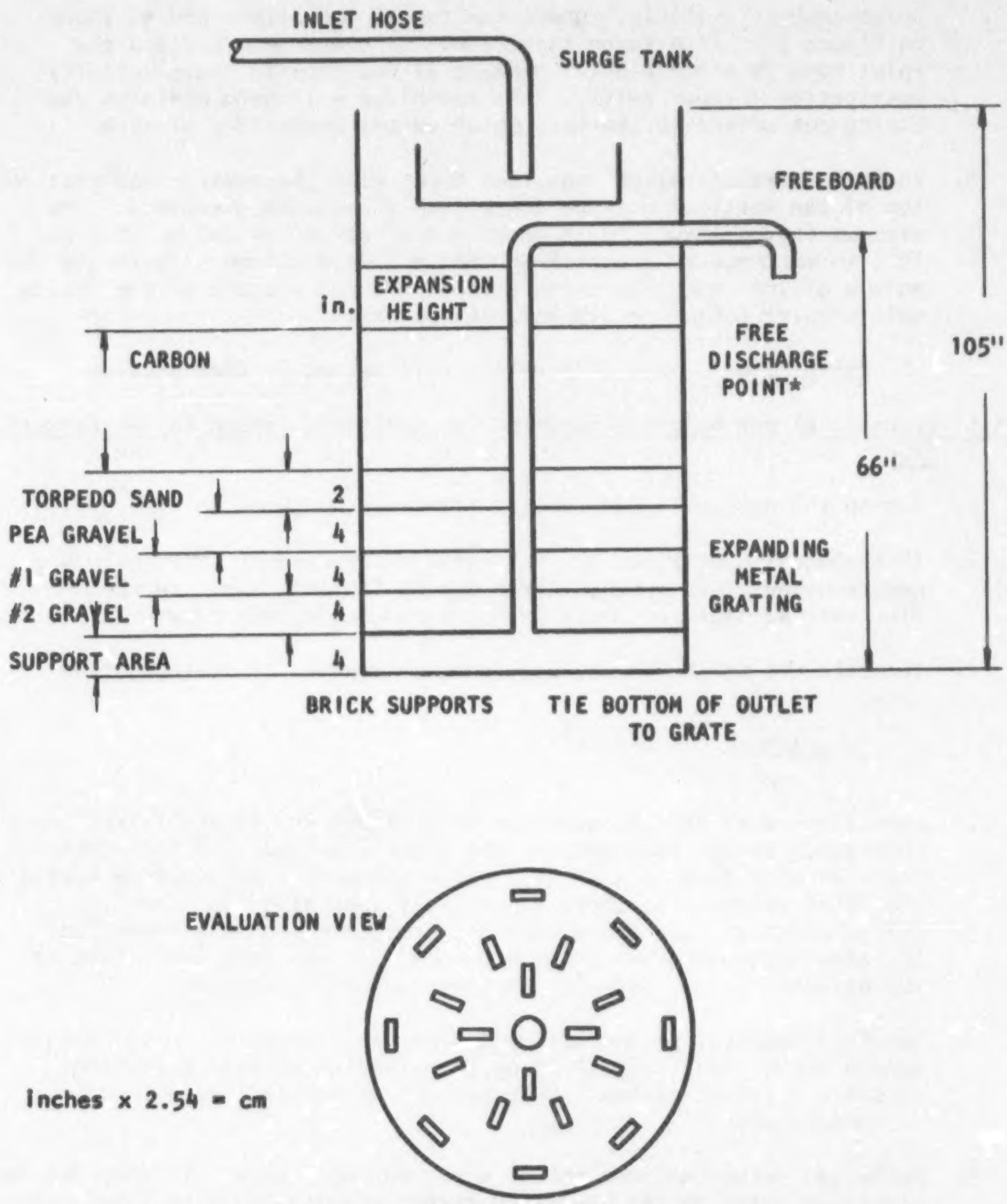
6. Install 1.2 m (48") of activated carbon which has been wetted for 48 hrs (see Preferred Option Figure 51). Backwash the filter to remove fines (see Section [illegible].2.5 for proper backwash method for removal of fines). A makeshift fines scoop is shown in Figure 48.

   Explanation: The carbon column should have 1.2 m (4 ft.) of standing water before introduction of the carbon. As this water is displaced by carbon it should be collected in the equalization basin. A mark 1.2 m (48") above the torpedo sand will insure the proper bed depth is obtained.

   CAUTION: All lines in which activated carbon is to be pumped must be at least 5cm (2 in.) in diameter. The lines must be kept as short as possible, i.e., the suction line is not to exceed 6m (20 ft.) and the discharge line will be no longer than necessary.

   Wetted activated carbon can also be installed by hand using buckets and shovels, etc.

7. Construct a surge tank to dissipate the inlet velocity head and act as a backwash trough. A good size would be 1/4 - 1/3 the column diameter. The surge tank may be supported by three cables suspended from the top of the column. Locate the bottom of the


INLET HOSE
SURGE TANK
FREEBOARD
EXPANSION HEIGHT
in.
CARBON
FREE DISCHARGE POINT*
105"
66"
TORPEDO SAND
2
PEA GRAVEL
4
#1 GRAVEL
4
#2 GRAVEL
4
SUPPORT AREA
4
EXPANDING METAL GRATING
BRICK SUPPORTS
TIE BOTTOM OF OUTLET TO GRATE
EVALUATION VIEW
PLAN VIEW FOR BRICK PLACEMENT

inches x 2.54 = cm

* DO NOT LET FREE DISCHARGE POINT EXTEND BELOW THE TOP OF THE BED.

Figure 52. Carbon column construction details.

surge tank .6 m (24 in.) above the top of the column bed as shown on Figure 52. If a surge tank cannot be constructed, place the inlet hose in a horizontal, tangential position to cause velocity dissipation through swirl. This technique will help minimize the boring out effect on the bed, which causes channeling of flow.

8. Install an equalization tank, any type, with the restriction that the top of the vertical wall be lower than the column discharge. The process volume should be at least 8.0 m^3 per m^2 of column (200 gal./ft^2) to accommodate one backwash for a single column. Calibrate the volume of this tank, by calculations, and put a scale on the inside wall showing 0.5 m^3 or 100 gal. increments.

   Explanation: This calibration will assist in flow setting.

6.3.5 Operational and Maintenance Steps for Activated Carbon Column Forward Flow

1. Set up the system in the forward flow mode as shown in Figure 51.

2. If backwashing of fines was not performed during or after column construction, care must be taken during filling, e.g., reduce flow rate so that the media is not bored out by the flow.

3. Throttle the inlet flow as necessary to achieve the desired flow rate.

   $$81.4 \frac{\text{l/min.}}{m^2} \quad (2\ \text{gpm/ft}^2)$$

   When flowing at design rate, the water level should stabilize. Mark this level on the tank wall as the clean bed head. If the water level is more than .3 m (1 ft.) above the bed at design flow during the first column run, there is probably some blinding from fines taking place and the fines removing procedure should be repeated. If, after backwash, the clear bed head does not come back close to the original level, consult the troubleshooting section.

4. Sample frequently at the effluent from each column or in the equalization tank. Have analysis done to establish effective loading possible for that carbon. When carbon has broken through, replace it immediately.

5. Activated carbon columns should never become fouled. If they do, the processes prior to the activated carbon column should be inspected and steps should be implemented to improve the product water of the processes. If the head rises to within 15 cm (6 in.) from the top of the tank, the column must be backwashed. However, backwashing is undesirable, because stratification of the carbon bed will occur, and should not be done unless absolutely necessary.

Backwash Mode

1. Set up the system for the backwash mode as shown in Figure 51. Restrain the backwash waste suction hose so that it will not be possible for it to become attached to the bottom of the surge tank. This would starve the pump and require that it be shut off momentarily to release the hose.

   Explanation: Backwashing the carbon column is intended to:

   a. Remove undesirable fines during filter preparation;

   b. Remove air bubbles and pockets during filter preparation;

   c. Remove collected suspended material.

2. Backwashing during carbon column preparation or for removal of fines and air bubbles and pockets: It is desirable to backwash for a total of 15 minutes at

$$30 \frac{\text{l/min.}}{\text{m}^2 \text{ of Filter}} \quad (0.74 \text{ gpm/ft.}^2)$$

   The accepted operational range for carbon column preparation backwashing is

$$20.4 \text{ to } 40.7 \frac{\text{l/min.}}{\text{m}^2 \text{ of Filter}} \quad (0.5\text{-}1.0 \text{ gpm/ft.}^2)$$

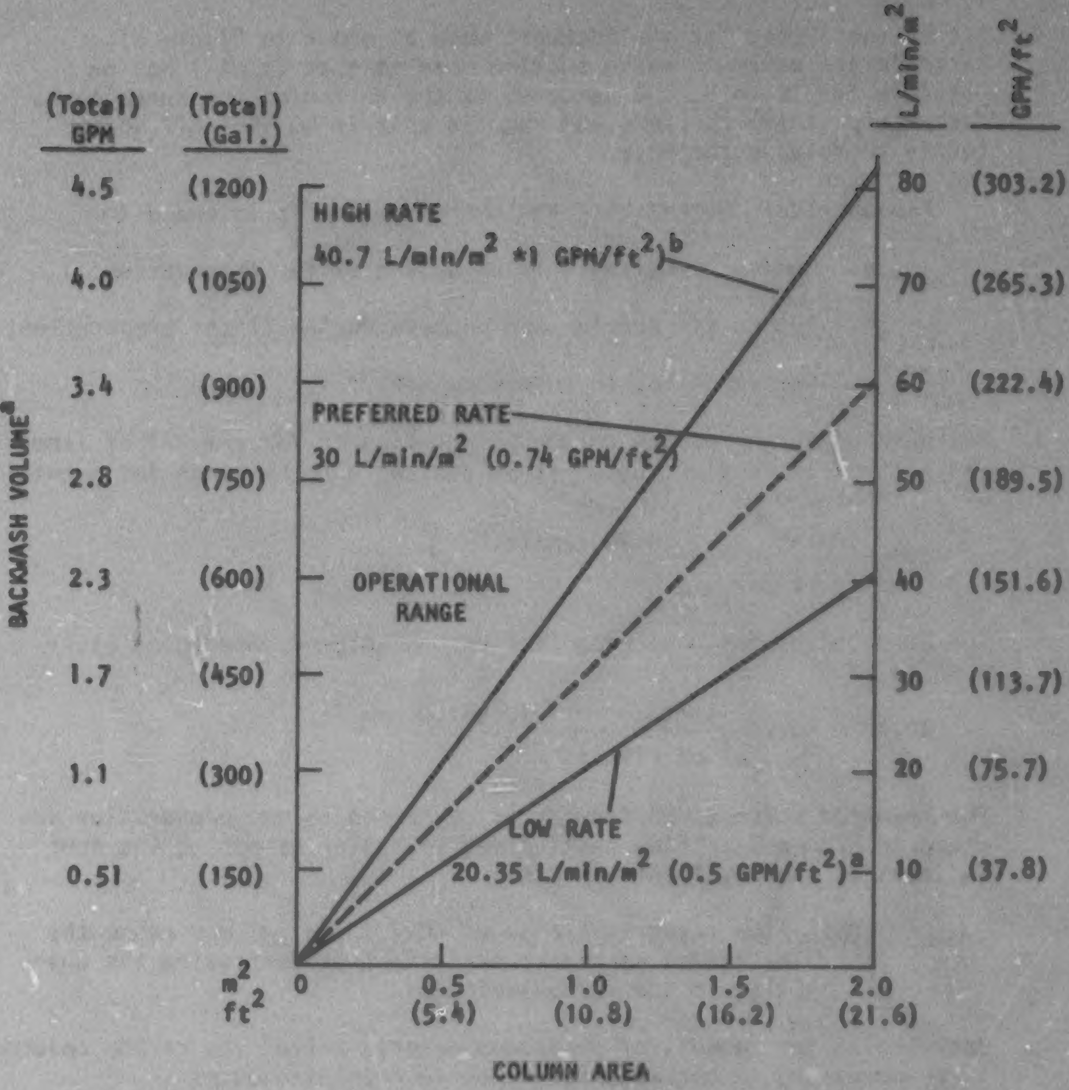
   The required volumes and flow rates or carbon column preparation are given in Figure 53. Flow setting may be easier by noting the drop in level of the equalization tank.

   CAUTION: Flow rates in excess of 40.7 l/min./m^2 may cause the activated carbon to stratify thus decreasing its ability to adsorb contaminants.

3. Backwashing for removal of suspended materials from the carbon column: It is necessary to backwash for about 10 - 15 minutes at

$$6.1 \frac{\text{m}^3\text{/min.}}{\text{m}^2 \text{ of Filter}} \quad (150 \text{ gpm/ft.}^2)$$

   The required volume and flow rates are given in Figure 53. Flow setting may be easier by noting the drop in level of the equalization tank.



[a] VOLUME IS BASED ON A 15 MINUTE BACKWASH

[b] RECOMMENDED BACKWASH RATES ARE FROM 40.7 L/min/m² to 20.35 L/min/m²

Figure 53. Carbon bed preparation by backwashing for fines removal.

Explanation: Efficient backwash requires that a certain flow rate termed the minimum fluidization velocity be passed upward through the bed causing all of the media particles to separate.

CAUTION: Do not allow an excessive flow rate to cause the activated carbon to be washed into the effluent trough. If you are in doubt as to whether this is happening or not, take a sample near the effluent trough with a glass jar and inspect for activated carbon carry-over.

Note whether the total bed is in agitation (desirable) or if the flow is being channeled (undesirable). Channeling is caused by poor backwash water distribution. Extended backwash period may help to effect better removal in this situation.

If backwashing does not effectively remove the suspended material or if extreme stratification occurs, the carbon must be replaced prior to further column use.

CAUTION: If backwashing at high rates above

$$\frac{40.7\ \text{l/min}}{\text{m}^2\ \text{of Filter}} \quad (2.0\text{gpm/ft}^2)$$

is performed, removal rates of the hazardous material may be significantly lowered.

4. After the backwash is completed the water above the carbon bed should be clarified and not murky. After the pump is turned off, a short duration must be allowed for the water to syphon backward through the backwash pump thus permitting the hose connection at the filter discharge to be separated without having a pressure behind it.

   Any fines should then be skimmed from the bed.

5. Removal of the exhausted activated carbon: The preferred removal method for the spent activated carbon is shown in Figure 54. The carbon should be submerged prior to and during removal.

   Explanation: Because activated carbon will dewater freely, it is necessary to pump water into column to keep the activated carbon slurried. The water can be replaced by intermittent operation of the backwash system or auxiliary pumps can be used to pump product water into the top of the column.

   CAUTION: Do not remove too much carbon or the underdrain

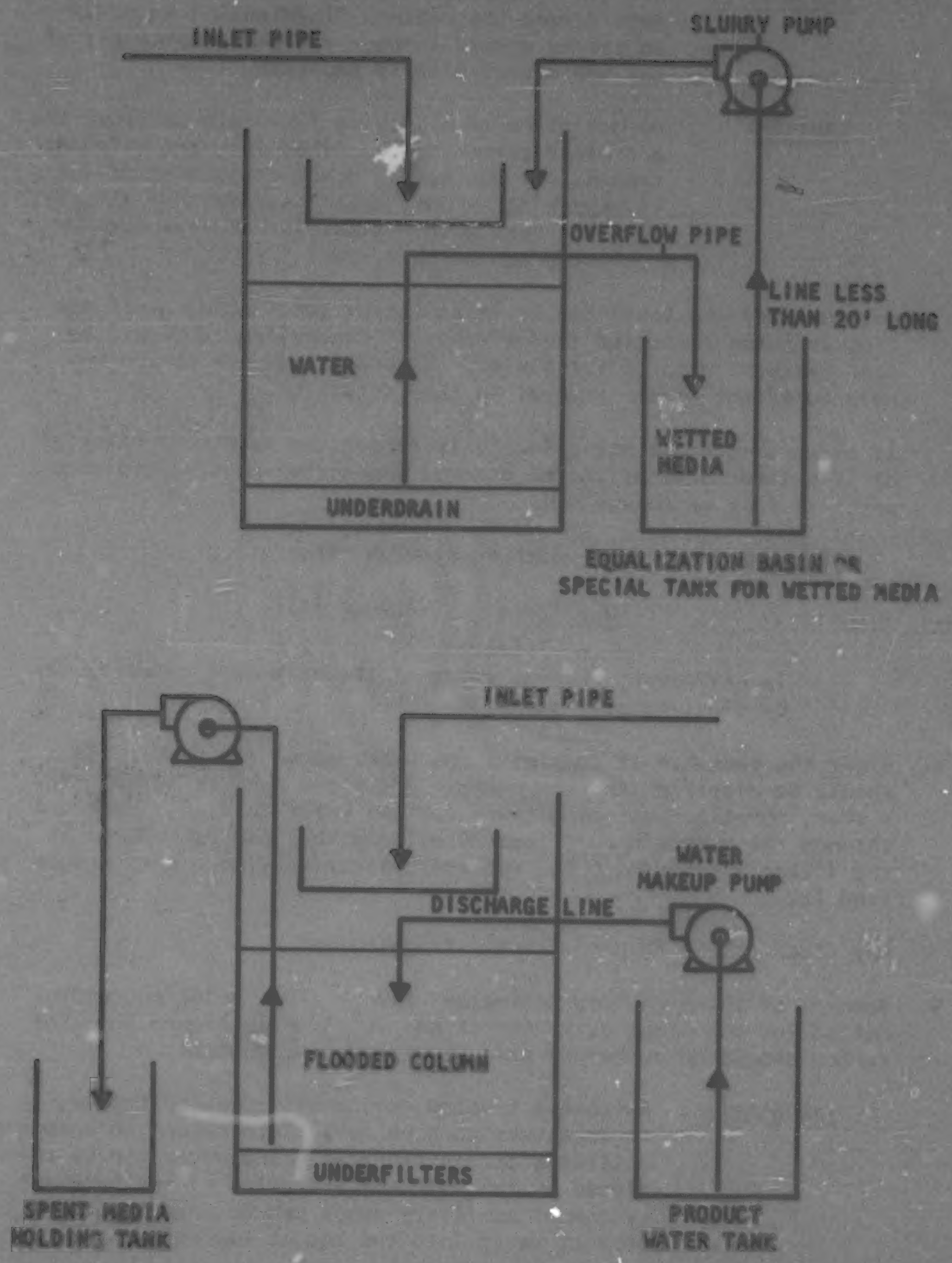

INLET PIPE
SLURRY PUMP
OVERFLOW PIPE
LINE LESS THAN 20' LONG
WATER
WETTED MEDIA
UNDERDRAIN
EQUALIZATION BASIN OR SPECIAL TANK FOR WETTED MEDIA
INLET PIPE
WATER MAKEUP PUMP
DISCHARGE LINE
FLOODED COLUMN
UNDERFILTERS
SPENT MEDIA HOLDING TANK
PRODUCT WATER TANK

Figure 54. Operating modes for carbon transfer

will be disturbed. To avoid this, it is preferred to leave an inch or two of carbon above the torpedo sand layer.

6.3.6 Activated Carbon Column Troubleshooting

1. Excessive Clean Bed Head - If backwashing does not permit return to the clean bed head, surface blinding may be occurring which can be alleviated by removing and replacing the top 5-12 cm (2-5 in.) of carbon from the bed. If suspended material is clogging the column, steps should be implemented to improve the feed water quality.

2. Poor effluent quality suggests:

    a. Too high a flow rate;

    b. Channeling of the bed (uneven distribution of flow);

    c. Excessive mixing of media;

    d. Exhausted activated carbon.

6.4 ION EXCHANGE

6.4.1 Process Description

Ion exchange is a process in which ions held by electrostatic forces to functional groups on the surface of a solid are exchanged for ions of a different species in solution (48). This process takes place on a resin which is usually made of a synthetic material. The resin contains a variable number of functional groups which establish both the capacity of the resin and the type of group removed. Various kinds of resins are available including weakly and strongly acidic cationic exchangers and weakly and strongly basic anion exchangers. The ions are exchanged until the resin is exhausted and then the resin is regenerated with a concentrated solution of ions flowing in a reverse direction. Various specific reactions occur but generally the reaction is as follows:

$$RI_x + I_c \longleftrightarrow RI_c + I_x$$

R = resin

I_x = exchangeable ion

I_c = contaminating ion

The ion exchange process is dependent on the type of resin involved, the specificity of the resin and the general ion content of the wastewater. Capacities of resins also vary with the manufacturer of the resin, the distribution of flow and concentration of contaminant.

The amount of resin required must be established by chemical tests done on wastewater for ion content. The best type of resin to use is established mainly by the specific contaminant to be removed, the amount of wastewater involved and the other ionic demand on the resin. A resin manufacturer must be contacted by the OSC to allow the correct resin to be chosen. The following information must be given to the manufacturer.

1. Name of compound to be removed,
2. Concentration of contaminant,
3. Amount of wastewater to be treated,
4. Chemical analysis of ions.

Cation removal (e.g. Metals/NH_4^+)	Anion removal
a. Hardness	a. Chloride
b. Sodium	b. Sulfate
c. Other cations	c. Nitrates
	d. Other significant anions

The resin manufacturer can then specify the amount and type of resin required to remove the entire contaminant from the waterway. Unless absolutely necessary, the resin will not be regenerated on site; once the capacity is depleted, the resin will be replaced, hauled away for regeneration and either returned for reuse on site or sent to storage.

Two types of off-stream treatment are available, 1) column exchange and 2) distribution of uncontained media into a tank. Column treatment is more common and more efficient. There are many similarities between ion exchange and carbon columns and some similarities to filters. The three systems have the following features in common:

1. Efficiency of the bed is dependent on good flow distribution which will provide uniform contact time for the entire fluid stream.

2. An underdrain system is necessary to prevent the media from exiting with the effluent water and to distribute backwash water.

3. Initial backwash is required to remove fines and air pockets, as well as to stratify the bed.

The carbon and ion exchange systems are similar in the following ways:

1. Termination of the cycle is established by "breakthrough" which indicates that the exchange capacity of the bed has been spent. This procedure is indicated by an increase in the concentration of the contaminant to be removed or by a change in pH (when strongly anionic or cationic resins are involved).

2. Use of the column as a filter causes inefficient use of the exchange capabilities. Therefore clarification processes including dual media filtration are necessary pretreatment steps.

3. Backwashing of these systems can be done, however, it is not recommended and the necessity of frequent backwashing indicates the malfunction of upstream processes.

However, ion exchange does have a high potential for fouling since the size of the resin particles is approximately the same as that of filter sand.

The amount of resin and the type required are established by the manufacturer. However, the design of the columns presented in this manual is based on two resins. Amberlite IRC-84 and IR-120. The OSC must compare the critical design data and then make appropriate changes in the design. (See Table 26).

TABLE 26. DESIGN PARAMETERS USED FOR ION EXCHANGE (49)

Parameter	Design criteria	
	metric	english
Loading rate	$81.4\ \frac{l/min}{m^2}$	2 gpm/ft^2
Loading range	$40.7 - 203.5\ \frac{l/min}{m^2}$	1-5 gpm/ft^2
Minimum bed depth	61 cm	24"
Expanded height	43.2 cm 65%	17"
Head loss (total head loss based on exp. height)	$\frac{0.07\ kg/cm^2}{m}$	$\frac{0.69\ ft\ of\ H_2O}{ft}$
Backwash rate	$\frac{244.2\ l/min}{m^2}$	6 gpm/ft^2
Backwash rate (range)	$\frac{162.8-488.4\ l/min}{m^2}$	4-12 gpm/ft^2
Backwash time	15 min.	15 min.
Backwash expansion	58.4 cm, about 50%	23", about 50%

6.4.2 Design for Ion Exchange Columns

1. Order the ion exchange media by contacting a manufacturer and giving him the wastewater characteristics indicated in the process description. See Section 7.4 for supplier.

   Explanation: Due to long lead times to receive the resin on site, it is essential to order the resin immediately. It is assumed that the resin will not be regenerated in the column or on site due to other hazards. Therefore, the amount of resin ordered must have capacity to handle the entire spill without regeneration.

2. Determine the required surface area from the process flow rate using Figure 55.

   Explanation: Required surface area is based on a design flow rate of 81.4 l/min/m^2 (2.0 gpm/ft^2).

   Operational ranges may vary from 40.7-203.5 $\frac{\text{l/min.}}{\text{m}^2}$ (1-5 gpm/ft^2) (49).

   Example: (From Figure 55). At 212 l/min., a bed area of 2.6 m^2 will be required if the ion exchange column is to be run at 81.4 $\frac{\text{l/min.}}{\text{m}^2}$

3. Select a tank from Section 7.3 with the following:

   a. A tank with vertical sides (Types A, F, B).

   b. An above-ground tank.

   c. A minimum height of 3.2 m (127 in.).

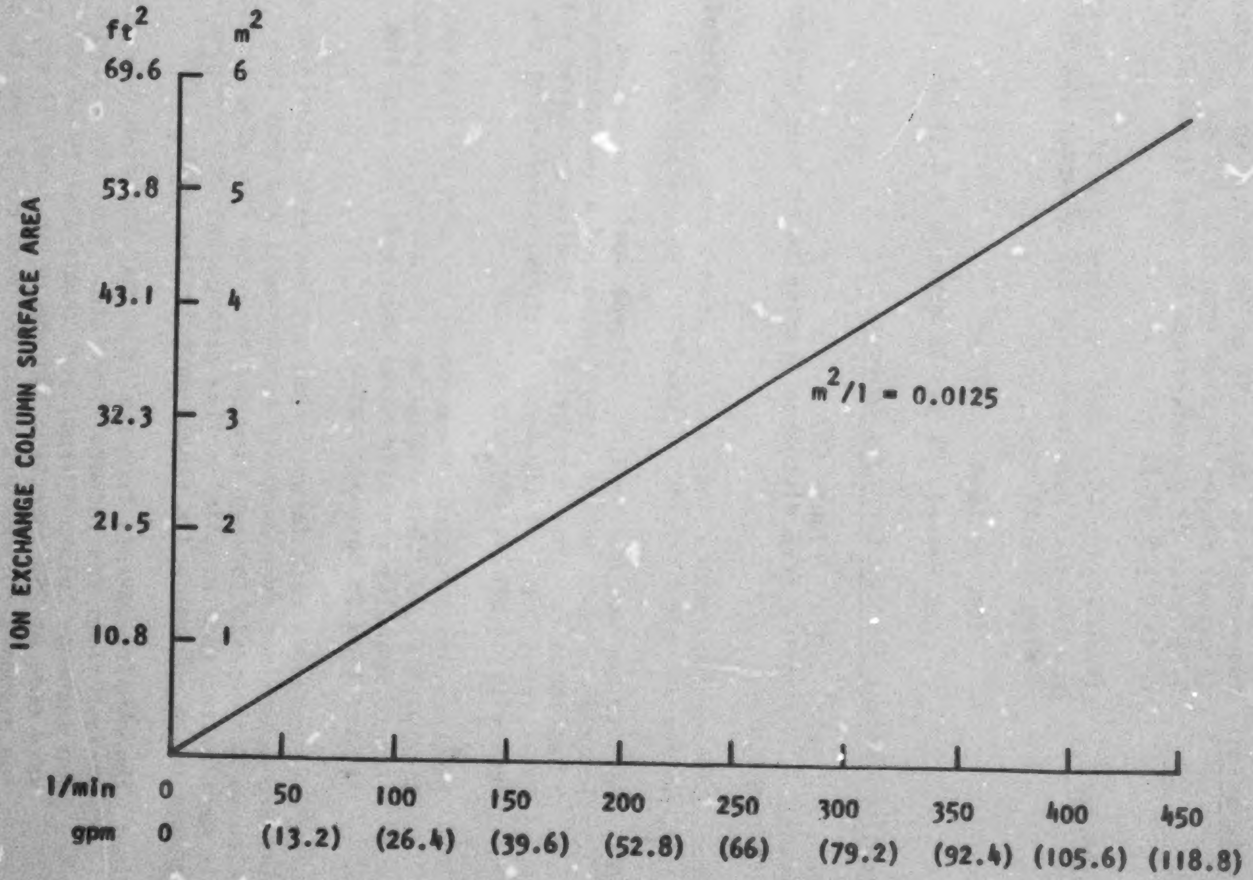
   d. A diameter in the range of 0.6-1.2 m (24-60 in.).

      Explanation: Over 1.2 m (60 in.) in diameter, a single outlet will probably not be sufficient to permit uniform flow distribution necessary for adequate backwashing.

   e. A flat bottom which can be uniformly supported, e.g., laying flat on the ground.

   f. Tank wall construction in which a hole may be machined for an outlet.

4. Order gravel for media underdrains from a local sand and gravel



[a]BASED ON A FLOW OF 2 gpm/ft^2.

Figure 55. Required surface area for ion exchange columns.

yard using amounts from Figure 45. Order equal amounts of pea gravel, and #1 and #2 gravels, and one-half that amount of torpedo sand.

Explanation: Pea gravel is about .31 cm (0.23 in.) in diameter; #1 gravel ranges in size from 1.25-1.9 cm (0.5-0.75 in.); #2 gravel ranges in size from 2.50-3.90 cm (1.0-1.5 in.).

Example: (From Figure 45). For the flow rate of 212 l/min., and the area requirement of 2.6 m^2 order the following quantities:

Torpedo Sand - 0.15 m^3

Pea Gravel, #1 and #2 gravels - 0.31 m^3.

6.4.3 Construction Options for Ion Exchange Columns

Preferred Option - Gravity Outlet (Figure 56)
Fully gravitational flow, with a free discharge leading to an equalization and backwash storage tank.

Explanation: Gravity flow rather than suction from a pump is desirable to prevent air blinding of the bed.

Advantages: Easy to operate and monitor effluent quality. Outlet location permits bed to remain submerged after batch runs, a desirable feature. Can be hydraulically connected with hoses and a total of six hose fittings; eliminating the necessity of piping and valves.

CAUTION: In cases where hazard to personnel would exist from contact with fluid, this option has a drawback in the necessity to manually transfer hoses when shifting from the forward flow to backwash mode.

Two pumps may be used handling both forward flow and backwash, providing the pump capacities are determined from backwash requirements and that they can be throttled to accommodate forward flow and backwash flow conditions. This option is well-suited to a parallel - flow arrangement utilizing multiple ion exchange resin columns and a single equalization tank.

Explanation: The benefit derives from the fact that backwash flow rate is four times the forward flow rate. Thus, in a single ion exchange column system, both pumps operate in the forward mode at 25% capacity. On the other hand, if say two ion exchange columns are used, the pump could operate at 50% capacity in forward flow, with the stipulation that ion exchange columns be backwashed individually.

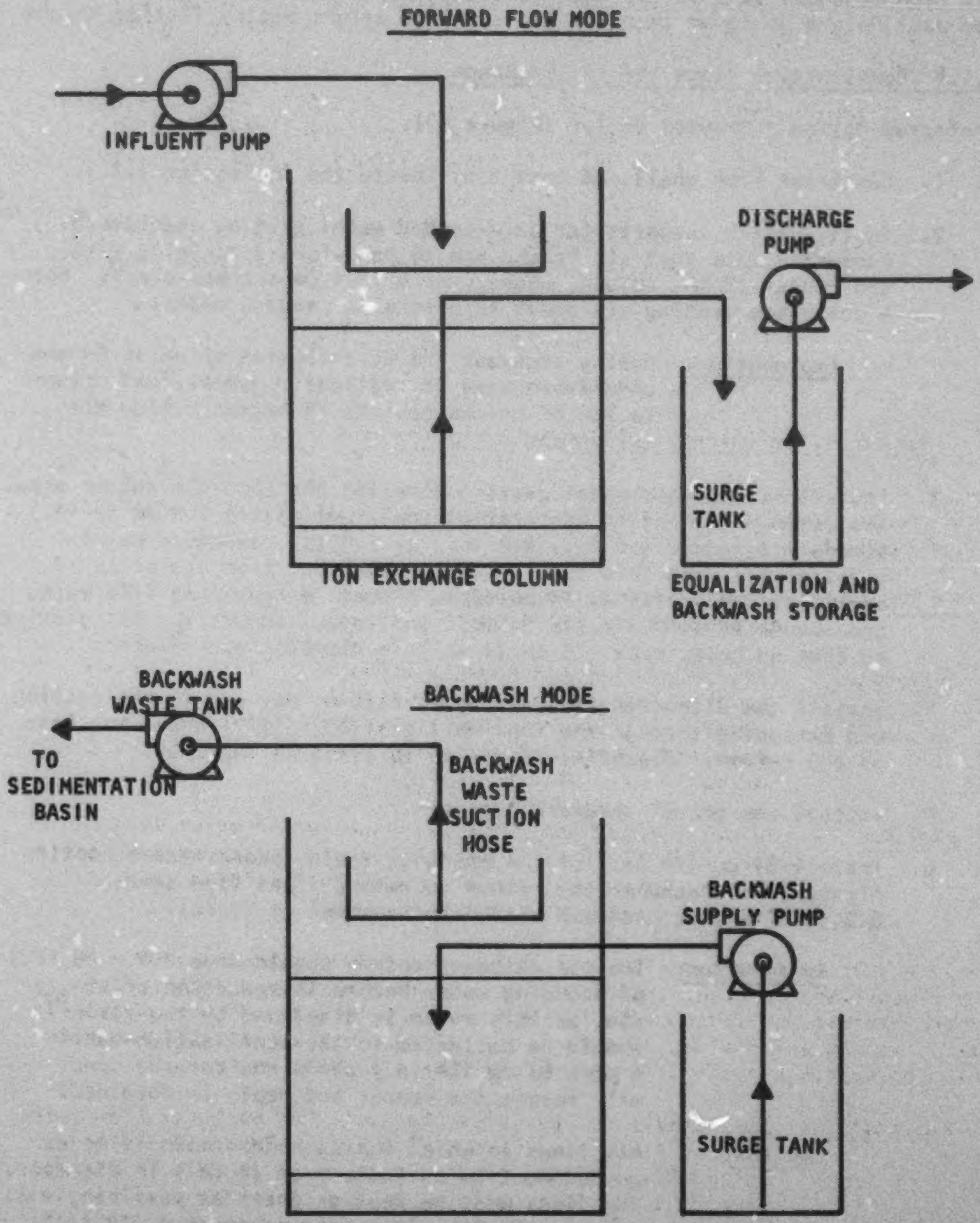

FORWARD FLOW MODE
INFLUENT PUMP
DISCHARGE PUMP
SURGE TANK
ION EXCHANGE COLUMN
EQUALIZATION AND BACKWASH STORAGE
BACKWASH MODE
BACKWASH WASTE TANK
TO SEDIMENTATION BASIN
BACKWASH WASTE SUCTION HOSE
BACKWASH SUPPLY PUMP
SURGE TANK

Figure 56. Preferred option and operating modes - ion exchange

Any type tank may be used for equalization, in-ground or out, provided that the wall height be lower than the ion exchange column outlet fitting height.

6.4.4 Construction Steps for Ion Exchange

Preferred Option - Gravity Outlet (Figure 57).

1. Construct tank shell and bottom as instructed in Section 7.3.3.

2. Install brick supports for an expanded metal grating underdrain support. Note that all bricks are to be oriented radially with the center of the column, except the bricks on the periphery. For a one piece grating use about 12 bricks per square meter.

   Explanation: During backwash the distribution of water in the underdrain area is critical. Symmetrical orientation of bricks assists in backwash flow distribution.

3. Install an expanded metal grating covering the complete column area. The maximum opening in the grating shall not pass a 2.5 cm (1 in.) sphere. Standard 3.0 lb., 4.0 lb., or 5.0 lb., expanded metal grating will meet this requirement. Construct from one piece if possible. If installed in multiple pieces, be sure the free edges are supported sufficiently (almost continuous support). Fit grating so that no holes over 2.5 cm (1 in.) in diameter are created.

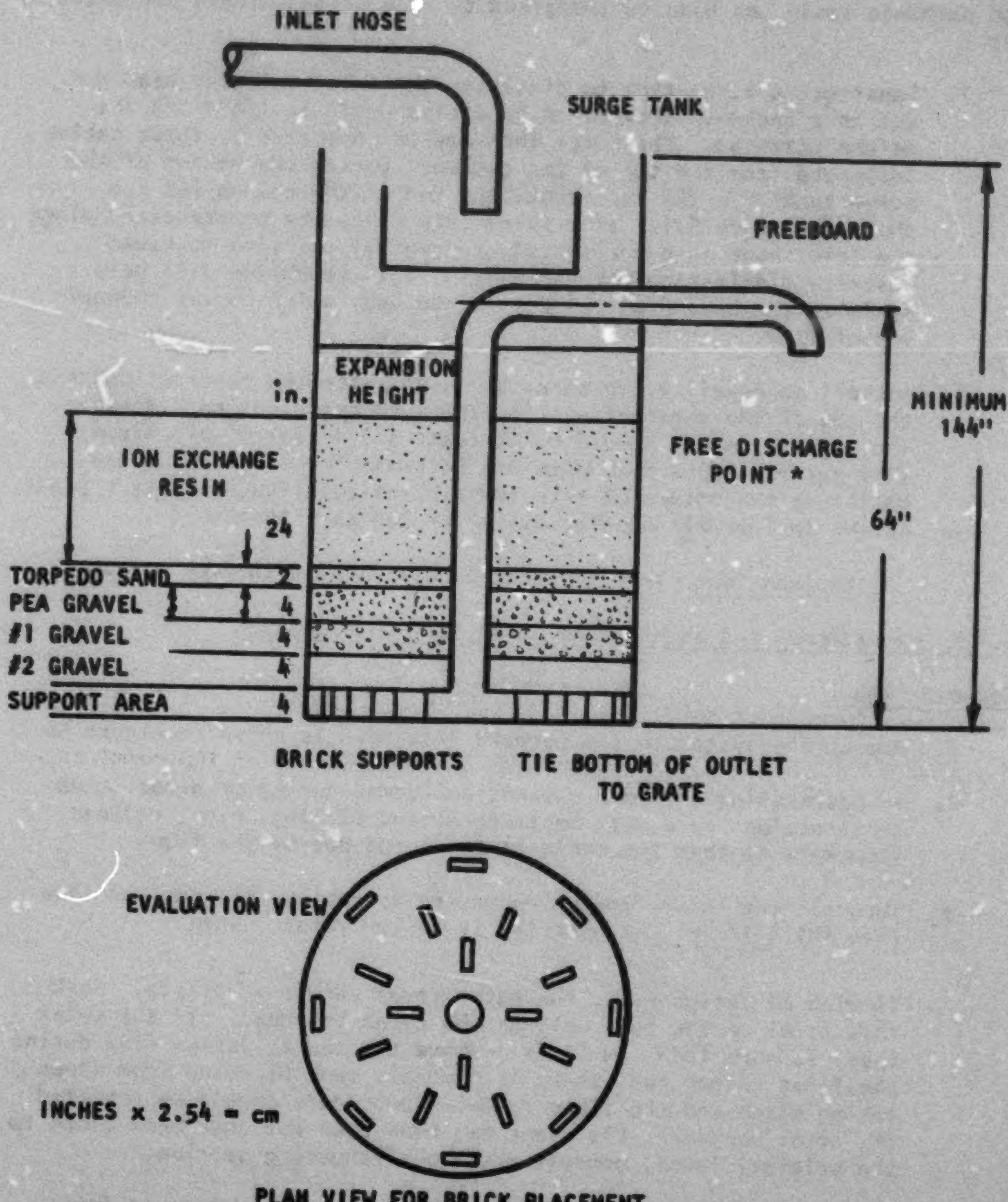
4. Install the discharge line as shown, tied on one end to the grating and extending through the tank wall at 1.83 m (72") above the base of the column. Discharge line size is given in Table 25.

5. Install the gravel underdrain layers.

6. Install 61 cm (24 in.) of ion exchange resin (see preferred option Figure 57). Backwash the column to remove fines (see section 6.2.5 for proper backwash method for removal of fines).

   Explanation: The ion exchange column should have 0.6 m (2 ft.) of standing water before introduction of the resin, as this water is displaced by the resin it should be collected in the equalization basin. A mark 61 cm (24 in.) above the torpedo sand will insure the proper bed depth is obtained.

   CAUTION: All lines in which ion exchange resin is to be pumped must be at least 5 cm (2 in.) in diameter. The lines must be kept as short as possible, i.e., the suction line is not to exceed 6 m (20 ft.) and the discharge line will be no longer than necessary.


INLET HOSE
SURGE TANK
FREEBOARD
EXPANSION HEIGHT
in.
ION EXCHANGE RESIN
24
TORPEDO SAND
2
PEA GRAVEL
4
#1 GRAVEL
4
#2 GRAVEL
4
SUPPORT AREA
4
FREE DISCHARGE POINT *
64''
MINIMUM 144''
BRICK SUPPORTS
TIE BOTTOM OF OUTLET TO GRATE
EVALUATION VIEW
INCHES x 2.54 = cm
PLAN VIEW FOR BRICK PLACEMENT

* DO NOT LET FREE DISCHARGE POINT EXTEND BELOW TOP OF BED

Figure 57. Ion exchange column construction details.

Ion exchange resin can also be installed by hand using buckets and shovels, etc.

7. Construct a surge tank to dissipate the inlet velocity head and act as a backwash trough. A good size would be 1/4 - 1/3 the column diameter. The surge tank may be supported by three cables suspended from the top of the column. Locate the bottom of the surge tank .6 m (24 in.) above the top of the column bed (as shown in Figure 57). If a surge tank cannot be constructed, place the inlet hose in a horizontal, tangential position to cause velocity dissipation through swirl. This technique will help minimize the boring out effect on the bed, which causes channeling of flow.

8. Install an equalization tank, any type, with the restriction that the top of the vertical wall be lower than the column discharge. The process volume should be at least 3.7 m^3 per m^2 of column (291 gal/ft^2) to accommodate one backwash for a single column. Calibrate the volume of this tank, by calculation, and put a scale on the inside wall showing 0.5 m^3 or 100 gal. increments.

   Explanation: This calibration will assist in flow setting.

6.4.5 Operational and Maintenance Steps for Ion Exchange

Forward Flow

1. Set up the system in the forward flow mode as shown in Figure 56.

2. If backwashing of fines was not performed during or after column construction, care must be taken during filling, e.g., reduced flow rate so that the media is not bored out by the flow.

3. Throttle the inlet flow as necessary to achieve the desired flow rate (81.4 $\frac{\text{l/min.}}{m^2}$ (2 gpm/ft^2) is design rate). When flowing at design rate, the water level should stabilize. Mark this level on the tank wall as the clean bed head. If the water level is more than .3m (1 ft.) above the bed at design flow during the first column run, there is probably some blinding from fines taking place and the fines removing procedure should be repeated. If, after backwash, the clear bed head does not come back close to the original level, consult the troubleshooting section.

4. Monitor the pH of the effluent which flows either into or from the gravity equalization tank. When the pH changes drastically from the normal operating value the resin is exhausted and flow must then be stopped and the resin replaced.

5. Ion exchange columns should never be allowed to become fouled. If they do, the processes prior to the ion exchange column should be inspected and steps should be implemented to improve the product water of these processes. If the head rises to within 15 cm (6 in.) from the top of the tank, it is time to backwash, which is undesirable.

Backwash Mode

1. Set up the system for the backwash mode as shown in Figure 56. Restrain the backwash waste suction hose so that it will not be possible for it to become attached to the bottom of the surge tank. This would starve the pump and require that it be shut off momentarily to release the hose.

   Explanation: Backwashing the ion exchange column is intended to:

   a. Remove undesirable fines during filter preparation;

   b. Remove air bubbles and pockets during filter preparation;

   c. Remove collected suspended material.

2. For ion exchange column preparation, removal of fines, air bubbles and pockets and suspended material removal, it is desirable to backwash for a total of 15 minutes at 244.2 $\frac{\text{l/min.}}{\text{m}^2 \text{ of filter}}$ (6.0 gpm/ft^2). The accepted operational range for ion exchange column preparation backwashing is 162.8 to 488.4 $\frac{\text{l/min.}}{\text{m}^2 \text{ of area}}$ (4.0 - 12 gpm/ft^2). The required volumes and flow rates for ion exchange column preparation are given in Figure 58. Flow setting may be easier by noting the drop in level of the equalization tank.

   Explanation: Efficient backwash requires that a certain flow rate termed the minimum fluidization velocity be passed upward through the bed causing all of the media particles to separate. Note whether the total bed is in agitation (desirable) or if the flow is being channeled (undesirable). Channeling is caused by poor backwash water distribution. Extended backwash period may help to effect better removal in this situation.

   CAUTION: Do not allow an excessive flow rate to cause the ion exchange resin to be washed into the effluent trough. If you are in doubt as to whether this is happening or not, take a

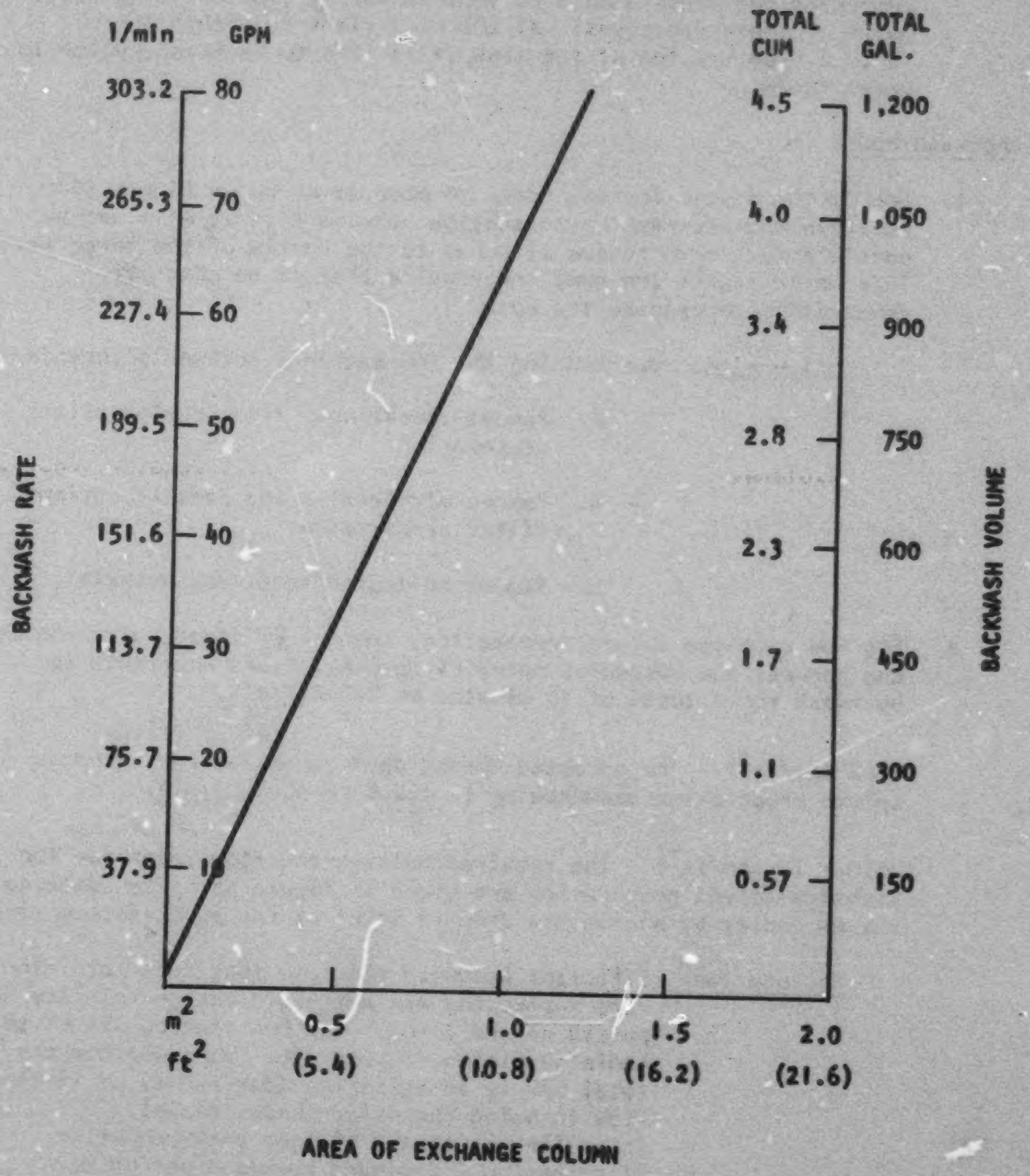


Figure 58. Backwash volume for ion exchange.

sample near the effluent trough with a glass jar and inspect for ion exchange resin carry-over.

As an alternative to backwashing, the ion exchange bed may be replaced. This would be desirable if the exchange capacity is almost exhausted.

3. After the backwash is completed the water above the bed should be clarified and not murky. After the pump is turned off, a short duration must be allowed for the water to syphon backward through the backwash pump thus permitting the hose connection at the filter discharge to be separated without having a pressure behind it. Any fines should then be skimmed from the bed, and make-up resin should be pumped into the bed to replace the resin that was removed.

4. Removal of the exhausted ion exchange resin: The preferred removal method for the spent resin is shown in Figure 59. The resin should be submerged prior to and during removal.

Explanation: Because ion exchange resin will dewater freely, it is necessary to pump water into the column to keep the resin slurried. The water can be replaced by intermittent operation of the backwash system or auxiliary pumps can be used to pump product water into the top of the column.

CAUTION: Do not remove too much ion exchange resin or the underdrain will be disturbed. To avoid this it is preferred to leave an inch or two of resin above the torpedo sand layer.

6.4.6 Ion Exchange Column Trouble Shooting

1. Excessive clean bed head - if backwashing does not permit return to clean bed head, 5-12 cm (2-5 in.) media may be removed and replaced. This procedure will only be necessary if feed water quality is high in suspended material which is causing surface blinding. If suspended material is clogging the column, steps should be implemented to improve the feed water quality.

2. Poor effluent quality - suggests:

   a. too high a flow rate (insufficient detention time);

   b. channeling of the bed;

   c. exhausted ion exchange resin;

   d. improper choice of resin - wrong type of anion/cation removal.

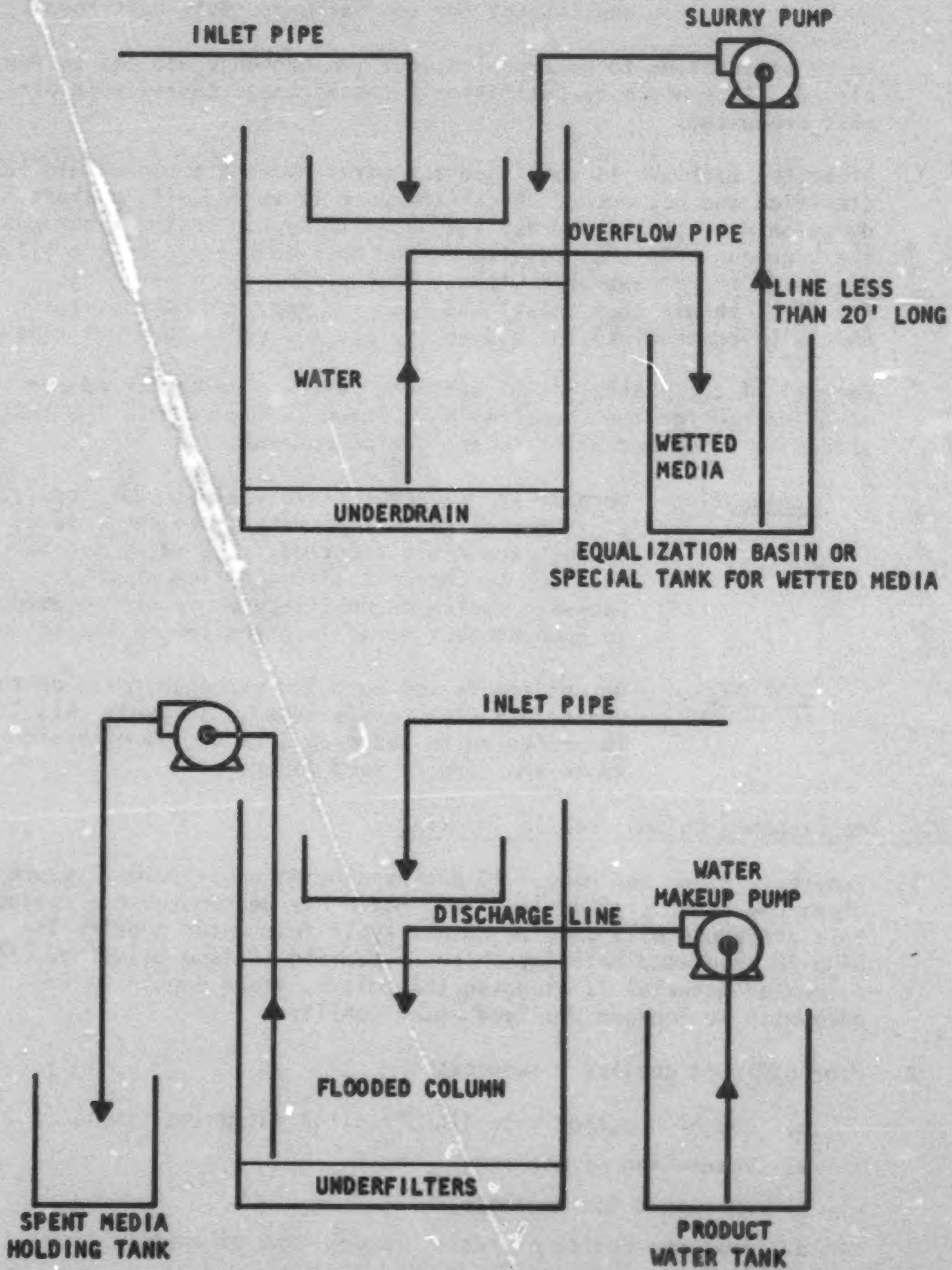

INLET PIPE
SLURRY PUMP
OVERFLOW PIPE
LINE LESS THAN 20' LONG
WATER
WETTED MEDIA
UNDERDRAIN
EQUALIZATION BASIN OR SPECIAL TANK FOR WETTED MEDIA
INLET PIPE
WATER MAKEUP PUMP
DISCHARGE LINE
FLOODED COLUMN
UNDERFILTERS
SPENT MEDIA HOLDING TANK
PRODUCT WATER TANK

Figure 59. Operating modes for ion exchange resin transfer

6.5 GRAVITY SEPARATION

6.5.1 Process Description

Gravity separation involves the removal from the water column of materials with a different specific gravity than water. Both flotation and sedimentation processes are included as an off-stream treatment system. In situ treatment is generally not applicable since dredging and absorbant processes have been covered in Section 4.3.

Sedimentation: Sedimentation is the removal of solid particles from a suspension through gravity settling (50). The process is used as a pretreatment and concentration step to reduce the load on downstream processes and utilize the natural concentrating procedure. Various factors affect the rate of settling including particle size and shape, density and viscosity of the water and other materials in the water column. The rate of settling can be predicted using theoretical equations, however, a field testing procedure is faster and more accurate.

Gravity separation has been included either as a necessary or optional process in all of the treatment schemes. The requirement for sedimentation preceeding the system is determined by the nature of the spill situation. A large amount of suspended solids in the influent, a strongly insoluble contaminant or sensitive downstream processes may lead to the use of a sedimentation system. Each situation must be evaluated on its own merits. Criteria are listed in Section 6.5.3.

Several problems are inherent when using sedimentation processes. The first difficulty is that the batch nature of the process requires a bank of parallel tanks to produce a continuous flow system. The number of tanks is dependent on the fill and draw rate, the detention time of settling and the amount of desludging required.

The desludging operation is tedious, time consuming, can be dangerous to personnel, and should be done as infrequently as possible. To reduce the amount of desludging, a presettler can be used which is set up for continuous desludging. The frequency of desludging is dependent on the nature of the sludge produced, the removal device and the type of tank used.

The tank operation is accomplished by:

1. Filling the tank up to the freeboard level by pumping fluid into the influent well. The well dissipates the velocity head and allows the fluid to overflow into the tank without disrupting the sludge blanket.

2. Allowing sufficient detention time for settling after filling operation is completed.

3. Drawing off supernatent by manually controlled suction hose which draws off the clear supernatent to the point where there

is danger of sludge entering the suction hose. After drawoff, tank refilling or desludging may proceed.

4. Removing sludge when a blanket has formed which has reduced the batch size substantially. Desludging is performed with a solids handling pump and special suction fitting.

There is an experimental settling test which can be used to establish flow rates and number of tanks for sedimentation. It is mandatory that a mixed sample of the wastewater be used to evaluate the settling capabilities. The sample is placed in a cylinder and the position of the interface with time is recorded. This data is then translated into a settling rate and evaluated. If the settling rate is less than .031 mpm (0.1 fpm) then chemicals may be added to increase the settling rate. The chemicals are added, mixed and flocculated, then the clumped solids are allowed to settle. There are several commonly used chemicals including ferric chloride, alum, and polyelectrolytes. The following paragraphs describe these chemicals and their use.

Ferric chloride: This compound is effective in clarifying both organic and inorganic suspensions. The final pH should be above 6 for best results so lime or caustic soda may be needed to control pH. Dilute suspensions require dosages of approximately 50-500 mg/l although larger dosages may be needed for concentrated or highly alkaline suspensions. If the wastewater is low in alkalinity, lime or caustic may be needed to raise the pH to 6 or higher. Excessive doses of ferric chloride will result in a brown colored effluent and should be avoided.

Alum: Aluminum sulfate is effective in clarifying both organic and inorganic suspensions. The pH should usually be controlled in the range of 6.5 to 7.5 pH and this control is generally crucial for good alum use. If a dilute suspension is to be treated, alum dosages of 100-1000 mg/l should be effective. Huge dosages may be needed for concentrated or highly alkaline suspensions. As with ferric chloride, suspensions low in alkalinity may require an addition of lime or caustic to produce the final pH range of 6.5 to 7.5

Organic Polyelectrolytes: Polyelectrolytes are available in anionic, cationic or nonionic form and may be effective alone when flocculating suspensions of inorganic materials (clay, soils, colloidals, metal salts etc). These polyelectrolytes are usually not effective alone when flocculating organic suspensions, but can be used with alum or ferric chloride for treating organic suspensions. Polyelectrolyte dosages vary with both the type of charge on the polymer and the type of suspension to be treated. Cationic polyelectrolytes are generally added in higher dosages, 1-10 mg/l in dilute situations (less than 100 mg/l suspended solids) and anionic or nonionic polymers are added at approximately 0.5 to 5 mg/l. When the solution is concentrated and the suspended solids concentration is greater than 1,000 mg/l add 1-300 mg/l of a catonic polyelectrolyte or 1-100 mg/l of an anionic or nonionic compound.

These chemicals are also used in combinations and various types of mixtures should be evaluated prior to establishing the treatment mechanism. When the chemicals are added, mixed and flocculated, the resulting solution and solids should be examined for the following:

a. A relatively clear internatant (i.e., the liquid between the particles). A cloudy internatant may indicate the need for more chemicals.

b. A medium to large but well defined floc. This is a good sign of correct chemical dosages.

c. Initial settling of the floc - the faster the floc drops out the better.

d. A relatively small sludge volume (3-5%) - even in a 100 ml graduate an approximate idea of sludge volume can be obtained. Excessive volumes of sludge from chemicals indicate future problems - a different chemical or smaller dosage may be desirable.

The following paragraphs describe the uses of the treatment chemicals to aid sedimentation. The total flocculation times are for full scale use. Laboratory times for mixing are 15-30 sec. and for flocculation are 30 sec. to 2 minutes.

Polyelectrolytes: Slowly add polyelectrolyte solutions to the waste while vigorously mixing the wastewater. Mix rapidly for 1 to 2 minutes to ensure dispersal. Then agitate the material at a speed just sufficient to keep the floc from settling and continue for 5 to 10 minutes. If more time is needed, increase the polymer dosage.

Alum Treatment: The order of addition of alum and then lime or NaOH may be critical. However either alum addition first or last may be the best for a given situation. Generally, alum addition followed by lime or NaOH addition will give satisfactory results and allows simple pH control. Alum should be added, mixed 1 to 2 minutes and then the lime or caustic can be added to achieve the proper pH. Again flocculation speed is established at the rate to keep the floc in suspension. The flocculation time should range from 5-15 minutes and if longer times are required, increase the alum dosage. If the floc is easily broken, add a polyelectrolyte to increase the strength.

Alum and polyelectrolytes: The use of polyelectrolyte will allow a stronger floc and a faster settling rate. Add the alum and lime or caustic as described previously. Flocculate from 2 to 5 minutes to allow creation of the desired alum floc. Then add polyelectrolyte in concentrations from 1 to 10 mg/l. Increase the rate of agitation during polymer addition to prevent settling and mix about 1 minute. Flocculate for 5-10 minutes or increase dosage of polyelectrolyte.

Ferric Chloride: (lime or caustic may be needed for pH control). Add ferric chloride and then mix for 2 to 5 minutes vigorously. Then add lime or caustic to raise pH to the desired level, mix an additional 2 to 5 minutes and then reduce mixing speed to allow flocculation. Flocculate at a sufficient speed to keep floc from settling for 5 to 15 minutes. If additional time is necessary, increase dosages or add polyelectrolyte.

Ferric chloride and polyelectrolyte: Use the same procedure as ferric chloride addition. After the second 5 minutes mix and add the polyelectrolye (1-10 mg/l). Mix at a higher rate to prevent settling and continue to mix approximately one minute. Then flocculate 5 to 10 minutes.

Once the chemicals and dosages have been determined, the system can be operated. To establish the efficiency of the unit, sampling should be done at both the influent and effluent of the batch and if the system is not operating properly, further bench tests may be needed.

Flotation: Flotation is used to separate materials with a specific gravity less then water. The contaminant rises to the top and is skimmed off periodically. This skimming process should be done during each batch, so the influent and effluent flows remain constant and do not disturb the downstream processes.

The flotation process operation has the same basic steps as are used in sedimentation except that skimming of floating substances is performed during each batch. A settled sludge blanket would probably accumulate but typically in far less proportions then in the sedimentation tank.

Flotation rates can be either calculated mathematically or measured in the field. The equation for rise rate is dependent upon the specific gravity and viscosity of the water, the specific gravity of the particle, and the estimated diameter of the globule. It is commonly assumed that the diameter is equal to 0.015. The rise rate is then equal to:

$$v_t = 0.0241 \frac{(Sw - S_c)}{u}$$

v_t = m/sec
Sw = sp.gr. of water
S_c = sp.gr. of contaminant
u = viscosity of water

The other method is measuring the rising position of the interface with time, in the same manner as a solids settling test. Once the rate is determined, the detention time is calculated:

$$\text{Detention time} = \frac{\text{height of tank}}{\text{rise rate}}\ 2^* \qquad \text{(2 is a safety factor)}$$

Once the detention time is calculated, the test can be re-done for that length of time and the scum volume estimated. The same chemicals and dosages used for settling tests can be used for gravity flotation.

6.5.2 Bench Testing Procedure - Gravity Separation

The following tests should be performed on the sample to establish the requirements for gravity separation. The procedure is as follows and an example appears in Figure 60.

Equipment Required:

1. 1 liter or similar graduated cylinder.
2. Raw wastewater.
3. Stop watch or wrist watch with second hand.
4. Ruler.
5. Chemicals
6. Pipette.
7. Pipette Bulb.
8. 100 ml graduated cylinders.

Procedure for Separation Tests:

1. Place graduate on a level surface.
2. Fill with 1,000 mls of sample.
3. Record position of the solids/liquid interface (POI) with time (see example data).

Calculations for Separation Tests:

1. Plot the interface versus time.
2. Establish the settling (or rise) rate from straight line portion of graph.
3. If settling rate (or rise rate) (from 2) is less than .031-0.153 mpm(0.1 to 0.5 fpm)do chemical addition prior to settling

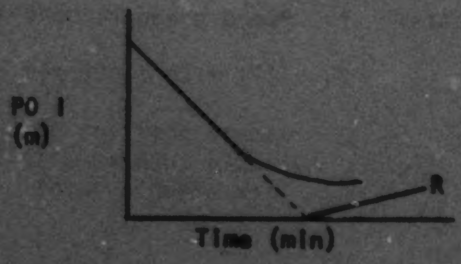
Procedure for Chemical Settling Tests:

1. Place wastewater in 100 ml graduated cylinders.

Time (min)	Volume of Solids Phase (ml)	POI (m)
0	1000	0.349
1	950	0.332
2	900	0.314
3	850	0.299
5	750	0.264
8	600	0.212
10	500	0.178
12	400	0.143
15	200	0.073
20	175	0.065
25	175	0.065
30	175	0.065

Plot the data using time as the X-coordinate and POI as the y-coordinate.

The slope of the straight line portion of the curve represents the settling rate of the solids in meters per minute



$$R = \frac{\text{Height of Cylinder}}{\text{Intersection of Straight Line with Abscissa}}$$

Figure 60. Example of settling test graphs.

2. Choose appropriate chemicals from Table 27.

3. Add in dosages at the endpoints of the range and various intervals.

4. Mix by covering the cylinder and inverting 3-4 times.

5. Flocculate by holding cylinder at the top and rotating for 1-2 minutes.

6. Observe floc formation and noticable settling.

   Explanation: Large floc or small floc which settles well is desirable/the clarity of the liquid portion around the floc is also indicative of the effectiveness. If dosage increases do not aid or improve settling, another chemical or a combination of chemicals should be utilized.

7. Choose chemical and proper dosage/scale up to 1,000 ml graduate size.

8. Repeat settling test but add chemicals/mix and flocculate and then record settling rate (steps 3-6).

Calculations for Chemical Settling Tests:

1. Calculate the amount of chemical required per gallon of wastewater (see Section 7.8)

2. Determine settling or rise rate as for non-chemical settling rate (i.e., graph + slope method).

Evaluation of Data from Settling Tests:

1. Calculate detention time as follows:

   detention time =

   $$\frac{\text{process ht. of tank}}{\text{settling (or rise) rate}} \times (2 \text{ to } 3)$$

2. Place new sample in 1,000 ml graduate, treat with established chemical dosage (if any) settle for calculated detention time, measure sludge height (as compared to height of cylinder between 0 ml - 1,000 ml) and sludge volume.

6.5.3 Evaluating Needed Pretreatment Schemes

There are various options available for pretreating the raw process flow. When the sedimentation tank is considered optional in the flow schemes listed in Table 22, or even when it is required, the pretreatment system must be evaluated. The following possible systems are described and numerically coded below for specification in the following criteria evaluations.

0. No Pretreatment - Pumpage directly from the water.

1. Equalization tank only - This tank is used to simplify pumping from the source to the next unit process and is needed so syncronization or smooth operation of pumps is not required.

2. Gravity Separation tank only - This tank is used to provide floating or settling solids removal. A bank of systems is necessary to provide flow through the process even during an hour's detention time.

3. Presettler and Sedimentation Tank - This system provides continuous solids removal in the presettler followed by sedimentation, often chemically treated.

Various methods can be used to establish the type of pretreatment required. When answering the following questions, the final choice of pretreatment is based on the highest number indicated by the criteria:

Criteria 1: Type of pumping system:	a. centrifugal	0
	b. reciprocating	1

Criteria 2:	Type of operation:	a.	suction point in water column only.	0
		b.	total dewatering of area.	2
		c.	surface skimming	2
		d.	bottom skimming, dredging	3
Criteria 3:	Next process in Sequence:	a.	filtration	2
		b.	precipitation	2
		c.	neutralization	1
		d.	oxidation/reduction	1
Criteria 4:	Settling Rates (from Bench Tests)	a.	greater than 1.53 mpm (5 fpm)	3
		b.	0.153-1.53 mpm (0.5-5 fpm)	2
		c.	less than 0.153 mpm (0.5 fpm)	0
Criteria 5:	Sludge Volume	a.	3% or more	3
		b.	0.5 - 3%	2
		c.	0.5%	1
Criteria 6:	Flow patterns in System:	a.	steady flow/continuous	0
		b.	steady flow/intermittent	1
		c.	fluctuating flow/continuous.	1
		d.	fluctuating flow/intermittent	1

In summary the following criteria justify the use of a presettler:

1. The raw flow is the product of a dredging operation. The high surface area of sedimentation tanks makes them difficult to desludge.

2. A reciprocating pump, such as a diaphragm pump, will transport raw flow to the sedimentation tank (especially tanks made from commercial swimming pools with thin plastic liners).

3. The raw flow pattern is intermittent or sporadic in nature.

4. The settling rate is greater than 1.53 mpm (5 fpm) or the sludge volume is greater than 3% of the influent volume.

A sedimentation tank is needed when:

1. It is to precede a filtration process - since sedimentation will allow removal of solids prior to filtration and permit an acceptable forward flow duration before backwash is necessary.

2. A settling rate of 0.153-1.53 mpm (0.5-5 fpm) and a sludge volume of less than 3% of the influent is available.

Explanation: As a pretreatment device for dual media filtration, the sedimentation tank plays a crucial part in establishing a reasonably long interval between backflushes (a maximum of one backflush per day is desirable).

6.5.4 Design Considerations

If gravity separation is to be accomplished without chemical precipitation, proceed with the following design considerations under either;

A. Sedimentation, or
B. Flotation

If chemical precipitation is required turn to Section 6.6.9.

A. Design Considerations for Sedimentation

1. Apply data from settling tests to establish a detention time.

$$\text{Detention time} = \frac{\text{process height}}{\text{settling rate}} \times 3 \begin{pmatrix}\text{safety}\\ \text{factor}\end{pmatrix} + \text{floc} + \text{mix time.}$$

Example:

Assume: process height = 0.91 m (3 ft.)
settling rate = 0.061 mpm (2 fpm)
floc time = 10 min.
mix time = 2 min.

Total Det.
Time = 45 + 10 + 2
= 57 min.

Explanation: The minimum process height is 3 feet and the large safety factor overcomes scaleup problem. If flocculation and mixing times are needed as shown in Table 27, add these to the detention time.

2. Choose a tank type (Section 7.3) using the following criteria:

   a. The shallower the tank, the shorter the detention time required for sedimentation. The minimum process depth should be 0.9 m (3 feet) and the minimum freeboard about 15 cm (6 in.). However, shallower tanks must be desludged more often.

   b. Choose a suitable desludging technique before finalizing tank selection:

      Flat bottom tanks - Tanks up to about 8 m (26 ft) in diameter can usually be desludged with a swimming pool cleaner with its flexible hose connected to a solids handling pump. The swimming pool cleaner incorporates a suction fitting mounted on rollers to allow movement along the tank bottom without tearing liners. Technique is limited to silty muds and other loosely packed sediments. Exclusions are gravel, fibrous debris, leaves, twigs, and grass which would justify the use of a presettler and/or screen chamber. A swimming pool cleaning device is also well suited for removing floating material.

      Slopesided tanks - In ground tanks can be excavated to provide sloped sides leading to a single low point. A hose suction can be located at the low point and used as a stationary desludging point. Long-handled push devices can be used to move the sediment toward the suction point. Screening can be fitted around the hose outlet for protection from fouling where necessary.

TABLE 27. TREATMENT CHEMICAL INFORMATION

Chemical	Use	Strength	Common dosage, mg/l	Field mix time[a]	Field floc time
Ferric Chloride	organic inorganic	25-100 mg/mℓ solution	~1000 mg/ℓ, 50-500 mg/ℓ + lime to pH 6 or or greater	complete dispersal of chemical (approx. 2-5 min).	5-15 min
Alum	organic inorganic	25-50 mg/mℓ solution	1000 mg/ℓ.SS 100-1000 mg/ℓ + CaO or NaOH to pH 6.5 to 7.5	Complete dispersal of chemical (approx. 2-5 min).	5-15 min
Polyelectrolytes	inorganic	0.5-1% solutions:		complete dispersal of chemical: (approx 1-2 min).	5-10 min
Cationic			SS <1000 mg/ℓ 1-10 mg/ℓ SS >1000 " 1-300 "		
Anionic			SS <1000 " 0.5-5 " SS >1000 " 1-100 "		
Nonanionic			SS <1000 " 0.5-5 " SS >1000 " 1-100 "		
Alum & Poly	inorganic/ organics to increase strength of floc	--	Alum 100-1000 mg/ℓ Poly 1-10 mg/ℓ	complete dispersal of chemical (approx 1-2 min) then poly & mix about 1 min.	2-5 min 5-10 min
Ferric chloride & Poly	inorganic/ organics to increase clarity	--	Ferric 50-500 mg/ℓ Poly 1-10 mg/ℓ	Complete dispersal of ferric (approx 1-2 min) then add poly & mix about 1 min.	2-5 min 5-10 min

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a. If required flocculation time exceeds the maximum time, try a higher chemical dosage.

c. Calculate the tank volume, V_n according to the formulae presented in Figure 73.

Example: Tank 6.1 m (20') diameter pool (Tank type A)
5.8 m (19') effective diameter
0.9 m (3') process height

$$V_n = .78\ D^2 \times Hp = .78\ (5.8m)^2 \times 0.9m = 23.6m^3$$

or, expressed in English units

$$V_n = 0.78\ (19ft)^2 \times 3 = 842.5ft^3 \times \frac{7.48\ gal}{ft^3} = 6360\ gal.$$

3. Calculate Fill and Draw Times

$$t_{fill} = t_{draw} = \frac{V_n}{\text{pump rate}} = \frac{V_n}{p}$$

Example:
Assume: $Q_p = 0.66cum/min$ (175 gpm)

Explanation: The process flow rate has been established by evaluating limiting factors (See section 5.4).

4. Calculate total time of tank use per batch.

$$T_T = \text{total time} = 2t_{(fill)} + t_d \text{ (detention time)}$$

Example: $T_T = 2\ (35.7)\ min + 57\ min$

$$t_{fill} = t_{draw} = \frac{30.3cum}{0.66cum/min} = 45.9$$

$= 128.4\ min$
$= 130\ min$

Explanation: The total time needed for operation is the fill time plus draw time plus detention time. As the tank fills with sludge, the total time will decrease, however, this calculation provides a safety factor. Higher pump rates for fill and draw will also provide a safety factor.

5. Establish frequency of desludging.

$$\text{Time between desludging} = \frac{0.25 \times Hp \times T_T}{\frac{\text{accumulation of sludge}}{\text{batch}}}$$

Explanation: Sludge can accumulate to 1/4 of the process height before desludging so the difficult desludging operation is less frequent.

$$\frac{\text{Accumulation of sludge}}{\text{batch}} = \frac{\text{height of sludge in test}}{\text{height of liquid in test}} \times \text{process height}$$

Example
Assume: 1.1 cm of sludge in test
36.4 cm of liquid in test
0.91m (3 ft) process height

$$\frac{\text{accumulation of sludge}}{\text{batch}} = \frac{1.1}{36.4} \times (0.910)_m$$

$$= 0.028\text{m/batch}$$

$$\text{time between desludging} = \frac{0.25 \times .91\text{m} \times 130 \text{ min/batch}}{0.028\text{m/batch}}$$

$$= 1056 \text{ min.}$$

$$= 18 \text{ hours}$$

Therefore desludging can occur once per day or once every 16 hours because the operations have a scheduled down time then.

6. Calculate the reduction in tank volume caused by sludge accumulation.

$$\text{amount of sludge accumulation between desludgings} = \frac{\text{amount of sludge}}{\text{batch}} \times \frac{\text{batches}}{\text{before desludging}}$$

$$\text{batches before desludging} = \frac{\text{time between desludging}}{\text{time per batch}}$$

Example:

$$\text{amount of sludge} = \frac{.028\text{m}}{\text{batch}} \times \frac{16 \text{ hr/between desludging} \times 60 \text{ min/hour}}{130 \text{ min/batch}}$$

Calculate new effective depth

Effective depth = process height - amount of sludge accumulated between desludgings.

Example:
Assume: process height = 0.91m
height of sludge = 0.207m
effective depth = 0.91m - 0.207m = 0.703m

Explanation: Based on the assumption that sludge is accumulating at a uniform rate during the cycle, the average amount of sludge in the tank throughout the cycle would be one-half of the total amount of sludge collected, making the above calculated effective depth too low by one-half of the final sludge height. However, the inefficiency of the drawoff operation only allows the tank to be drawn down to twice the height of the sludge blanket which substantiates the above equation.

Explanation: The effective volume can then be used in future calculating.

New effective volume:

$$V_n \text{ eff} = \frac{\pi D^2}{4} \times \text{eff depth}$$

Example:

Assume: 5.8m - Tank diameter
eff depth = 0.703m
V_n eff = 18.6 cum

7. Calculate Process Volume Required

$$Vp = Qp\,(T_T)$$

Example:

Assume: Qp = 0.66 cum/min
T_T = 130 min.
Vp = 0.66 cum/min x 130 min.
= 85.8 cum

Explanation: Qp is set by systems approach. T_T is calculated in Step 4.

8. Calculate number of tanks needed.

$$n = \frac{V_p}{V_n \text{ eff}}$$

Example:

$$\frac{Vp}{V_n \text{ eff.}} = \frac{85.8 \text{ cum}}{18.4 \text{ cum/tank}}$$

n = 4.66 tanks

n ≐ 5 tanks

9. Calculate the sludge volume accumulated per day: sludge volume/day =

$$= \text{height of sludge} \times 2 \times \frac{\text{number of desludges}}{\text{day}} \times \frac{\pi D^2}{4}$$

$$= 0.20\text{m} \times 2 \times 1 \times \frac{3.14 \times (5.8)^2\text{m}}{4}$$

$$= 10.9\ \frac{\text{cum}}{\text{day}}$$

10. Calculate number of sludge tanks needed:

$$n_{sl} = \frac{\text{sludge volume/day}}{\text{volume of 1 tank}}$$

Example: volume of 1 tank = 23.6 cum

$$n_{sl} = \frac{10.9\ \text{cum/day}}{23.6\ \text{cum/tank}} = \quad 0.5 : \text{need one tank}$$

B. Design Considerations for Flotation

1. Apply data from the batch tests to establish a detention time.

$$\text{Detention time} = \frac{\text{process height}}{\text{rise rate}} \times 3\ (\text{safety factor}) + \text{floc time} + \text{mix-time}$$

Example: process height = 1.22m (4 ft)
rise rate = 0.061 mpm
no chemicals added

$$\text{Detention time} = \frac{1.22\text{m}}{0.061\text{mpm}} \times 3 = 60\ \text{min}$$

2. Choose a tank type (Section 7.3)

Remember: The system must be skimmed between each operation so the tank geometry should be chosen to simplify this process (Tank diameter should be 7.63m (25') maximum).

Example: 5.49 (18') diameter pool
5.19 (17') effective diameter
1.22 (4') process height

$$V_n = 0.78 \times D^2 \times h_p = 0.78\ (5.19\text{m})^2 \times 1.22\text{m} = 25.63\ \text{cum}$$

$$V_n\ (\text{gal}) = 0.78 \times (17\text{ft})^2 \times 4(\ \times 7.48\ \frac{\text{gal}}{\text{ft}^3})$$

$$= 674\ \text{gal.}$$

3. Calculate the fill and draw time.

$$t_{fill} = t_{draw} = \frac{V_n}{\text{pump rate}} = \frac{V_n}{Q_p}$$

Example: 0.568 cum/min
Assume: Q_p (150 gpm)

$$t_{fill} = t_{draw} = \frac{25.63}{0.568 \text{ cum/min}}$$

$$= 45 \text{ min.}$$

4. Assume a time needed for skimming the tank.

Example:
Surface area = $0.78D^2$
= $21 m^2$ or $225 ft^2$
Time = $1.07 \text{ min}/m^2 \times 21 m^2$
= 22.5 min

Explanation: Assume a skim time of $\frac{1.07 \text{ min}}{m^2}$ of surface area. However, some skimming can be done during the operation (i.e., detention time) and the draw time and this will reduce the time.

5. Calculate total time of tank use per batch.

T_T = total time = $2(t_{fill}) + t_d$ (detention time) + t_s (skim time)

Example: T = 60 + (45)2 + 23
= 173 min.

Explanation: The maximum time for these operations is shown. However, the total time may be reduced if some of the skimming could be done at the same time the tank is drawn down.

6. Calculate the reduction in tank volume caused by settled sludge accumulation.

   a. Calculate amount of sludge accumulated per batch.

   Assume: from settling tests the sludge = 0.3% of total height

   $$\text{sludge accumulation} = \frac{\text{sludge accumulation} \times H_D}{100}$$

Example: $= \frac{0.3 \times .22\text{m}}{100} \cong 0.0037\text{m/batch}$

b. Amount of sludge accumulated per day

Assume: 16 hours of operation

$$\frac{\text{amount of sludge}}{\text{day}} = \frac{\text{amount of sludge}}{\text{batch}} \times \frac{\text{batches}}{\text{day}}$$

$$\text{batches per day} = \frac{\text{time of operation per day}}{T_T}$$

Example:

$$\frac{\text{amount of sludge}}{\text{day}} = \underline{0.0037\text{m/batch}} \times \frac{16\text{ hour/day} \times 60\text{ min/hr}}{173\text{ min/batch}} = \underline{0.021\text{m}}$$

c. New effective depth

$$H_p - \frac{\text{sludge accumulated}}{\text{day}} = \text{effective depth}$$

d. New effective volume

$V_n = 0.78 \times (5.19\text{m})^2 \times 1.199\text{m}$

$= 25.19$ cum

$V_n\ (\text{gal}) = 0.78\ (17)^2\ \text{ft}^2 \times 3.93\ \text{ft} \times .48\ \text{gal/ft}^3 = 6627$ ga.

Explanation: The skimming volume is not included since the tank is skimmed each time and the volume is not affected.

7. Calculate the process volume required.

$V_p = Q_p\ (T_T)$

Example: $= 0.568$ cum/min x 173 min

$= 98.3$ cum

8. Calculate the number of tanks needed:

$$n = \frac{V_p}{V_{n\ \text{eff}}}$$

Example: $n = \frac{98.3\text{ cum}}{25.19\text{ cum/tank}} = \frac{25950\text{ gal}}{6627\text{ gal/tank}}$

$n = 3.9 = 4$ tanks

9. Calculate sludge volume and tank requirements as shown in steps A-9 and A-10.

6.5.5 Construction of Gravity Separation Tanks and Presettlers

If gravity separation is to be accomplished without chemical precipitation, proceed with the following construction steps under either:

A. Sedimentation, or
B. Flotation

If chemical precipitation is required turn to Section 6.6.9. Presettlers are described under C in this section.

A. Construction of Sedimentation Tanks - Tank sizing has already occurred as part of the design process in Section 6.5.4. The remaining construction steps involve tank installation, inlet velocity head dissipation and supernatant drawoff (see Figure 61).

   1. Tank Installation - Small areas where the tank bottom is flat are required at the inlet and outlet. This is no problem when using a flat bottomed tank but must be considered during excavation for sloped side, in ground tanks. The tank liner at those spots should be protected with a rubber sheet.

   2. Obtain or construct an inlet well according to the following guidelines:

      a. The configuration of the tank is not important provided that it be sturdy and have a level top edge.

      b. Height: 3/4 process water height.

      c. Total length of top edge = 0.336 cm/lpm (1/2 in. per gpm) (If 55 gallon drums are used, Figure 0.378 cum/min (1,000 gpm) per drum. Multiple drums can be used with a flow splitter. See Section 7.4.2.2.

      d. Whenever possible, employ a non-removable section of inlet hose which can be adequately supported. Extend the hose about a quarter of the way down into the tank.

      e. Ballast the tank with at least 45.5 kg (100 lbs) if possible.

      Explantion: When the inlet pump is shut off, the well will syphon back to the level of the hose end. The buoyancy force

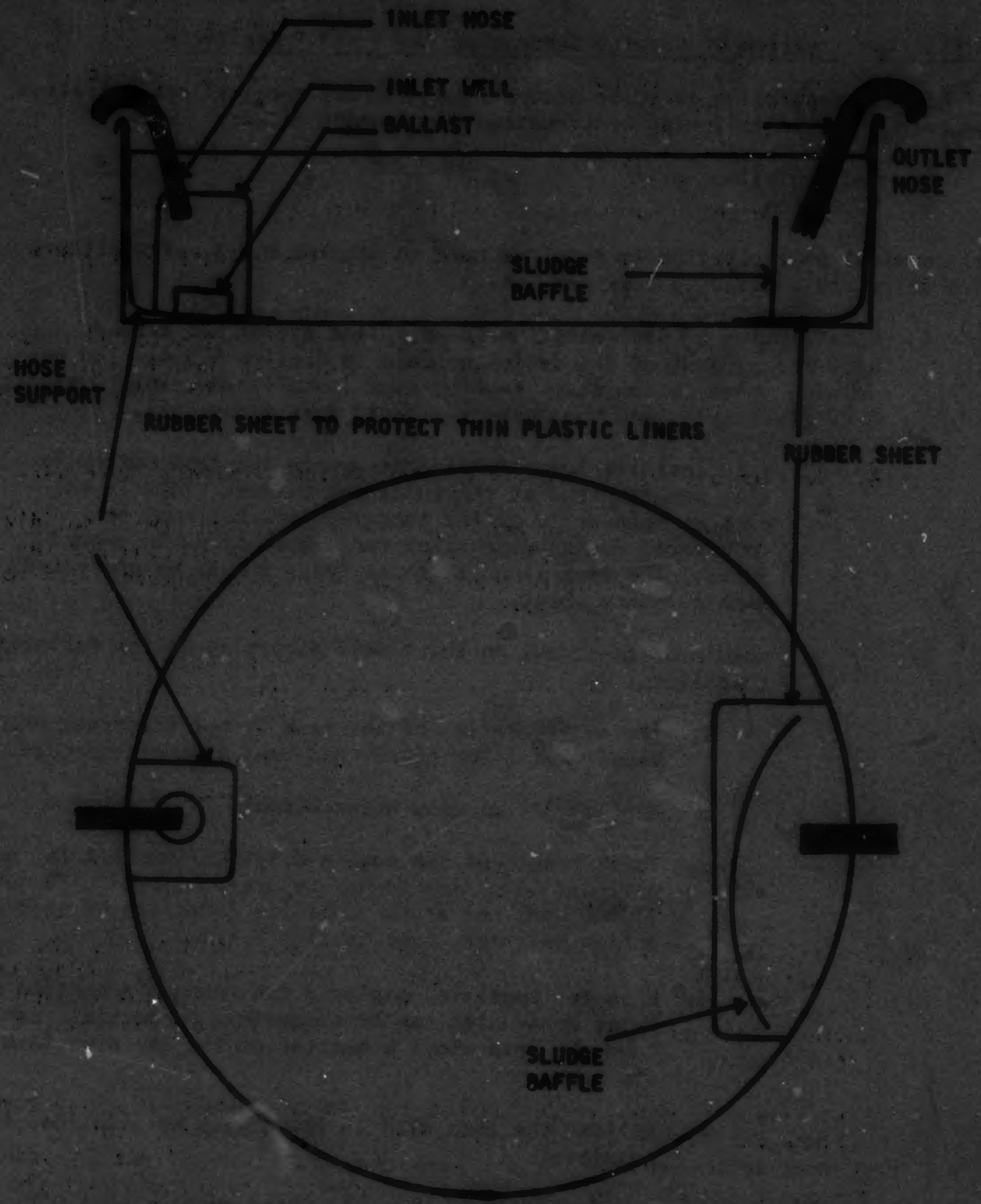

INLET HOSE
INLET WELL
BALLAST
OUTLET HOSE
SLUDGE BAFFLE
HOSE SUPPORT
RUBBER SHEET TO PROTECT THIN PLASTIC LINERS
RUBBER SHEET
SLUDGE BAFFLE

Figure 61. Batch sedimentation tank schematic.

could cause the wall to tip over. Remedies are to shorten the wall or not extend the hose down as far.

3. Construct a sludge baffle according to the following guidelines (see Figure 61).

   a. Materials heavier than water or ballasted.

   b. Height - approx. 1/2 process height.

   c. Length to form a semicircle around the drawoff point, 180° from the inlet.

      CAUTION: The baffle should not be constructed as a dam and therefore suitable gaps should be present to allow the supernatant to flow easily around the baffle during drawoff.

4. Serrate the end of the outlet hose as shown below (Figure 62).

   Explanation: A square edge hose will attach itself solidly to the tank by virtue of the suction and require that the drawdown pump be turned off to release it.

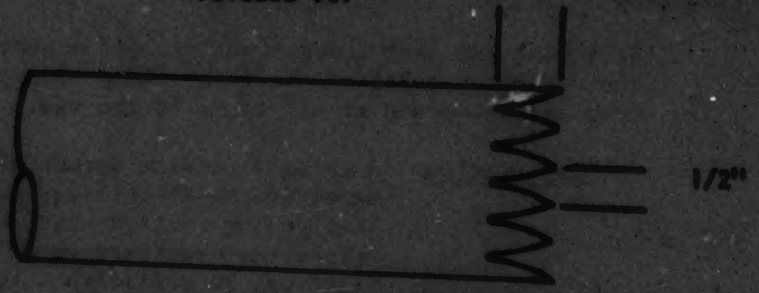


Figure 62. Serrated outlet hose.

B. Construction of Flotation Tanks - Because sludge will accumulate in a flotation tank the basic construction is identical to the sedimentation tank. The only exception is the use of a floating barrier around the outlet to prevent any uncollected floating materials to be drawn into the influent.

C. Presettlers - These devices do not attempt to produce quiescent conditions but rather to allow separation of gravel, sand, fibrous debris, leaves, grass etc., as well as to act as equalization tanks and pulse deadener for reciprocating pumps before transferring the fluid by centrifugal pump to the sedimentation tank. There are a wide variety of ways a presettler could be constructed. Only one technique is being shown here to illustrate possible ways in which the desired separation can be accomodated.

Option I - Features: Continuously Operated Swirl Tank (Figure 63).

1. Velocity is dissipated through a horizontal flow pattern which causes the tank contents to swirl.
2. The incoming fluid travels around the complete periphery of the tank before being discharged.
3. Sequential screens from coarse to fine can separate suspended and floating materials from the swirling fluid.
4. Desludging and skimming can be performed continuously.

6.5.6 Operational and Maintenance Steps

A. Sedimentation

1. Fill the tank to the desired freeboard height.
2. Allow the contents to settle for a specified detention time.
3. Draw off the supernatant to the point where solids are at the point of flowing around the outlet baffle.

Desludging

1. Following the last supernatant drawoff operation draw down the entire contents of the tank Keep the suction fitting or hose end submerged at all times in the mud.

   Explanation: A certain minimum amount of water is necessary to effectively pump solids. Keeping the suction head in the mud will retain the necessary water in the tank. Water can be replenished to facilitate solids removal as necessary.

2. Reconcentration of Settled Sludges - Further solids separation will occur in the sludge storage tank and so supernatant drawoff can again be performed. Chemical precipitation as described in Section 6.6.9 can also be used to increase the separation process.

B. Flotation

1. Fill the tank to the desired freeboard height.
2. Allow the suspended material to float to the surface for a specified detention time. Draw off the underflow, taking precautions not to draw in settled sludges. Draw down can probably be started during the latter stages of skimming.

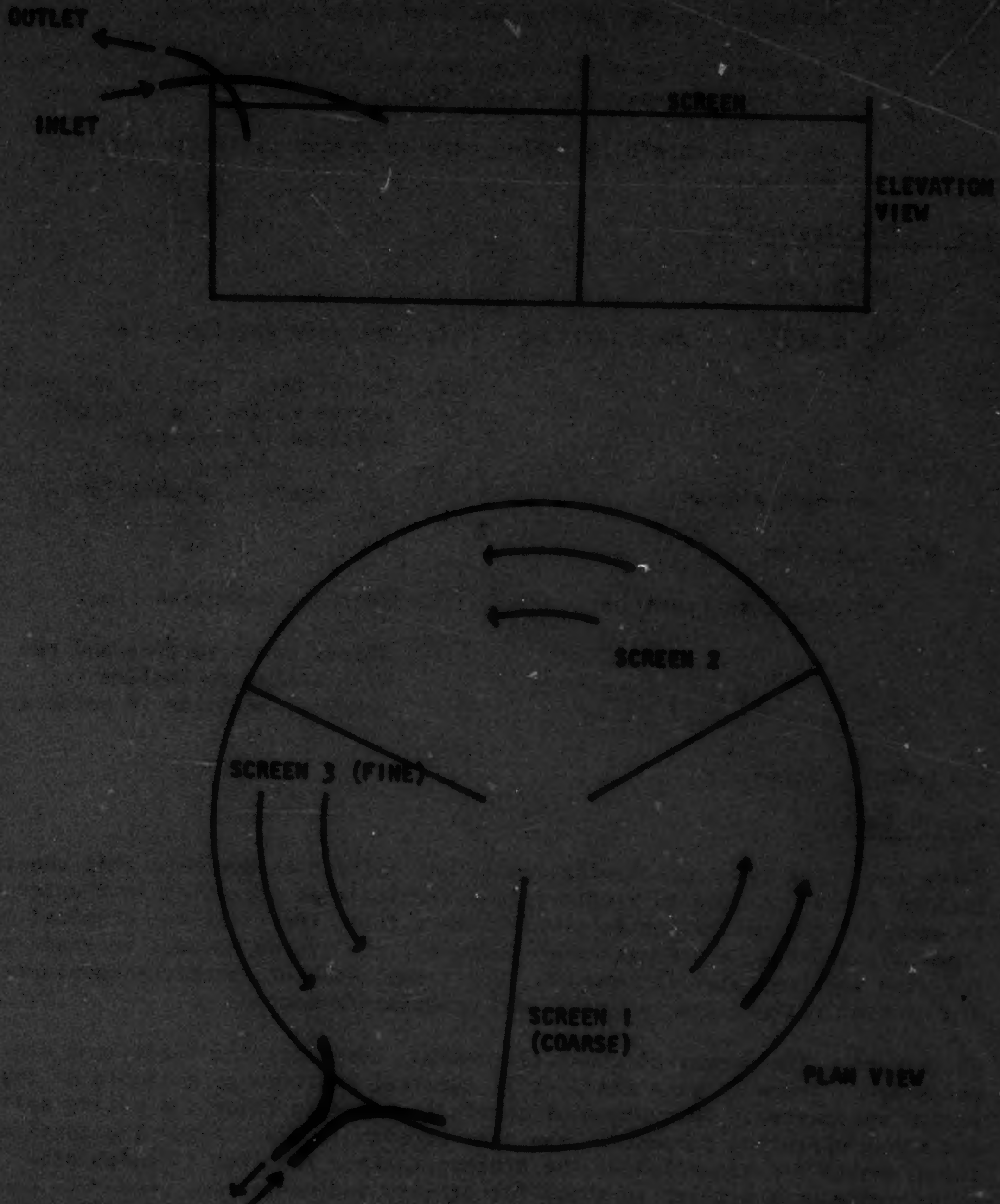

OUTLET
INLET
SCREEN
ELEVATION VIEW
SCREEN 2
SCREEN 3 (FINE)
SCREEN 1 (COARSE)
PLAN VIEW

Figure 63. Continuous operated swirl tank presettler.

1

Desludging

1. Desludge the tank during shutdown times as required.

2. Reconcentration of flotated and settled wastes can be performed provided the wastes are kept separated.

3. Skim tank carefully taking care to remove as little water as possible.

6.5.7 Troubleshooting

A. Sedimentation

No settling or poor settling	1. Increase settling time.
	2. Repeat bench testing and revise system to include chemical addition if necessary.
Too much sludge	1. Add necessary presettlers.

B. Flotation

No effective flotation	1. Increase detention time.
	2. Repeat bench testing and revise system to include chemical addition if necessary.

6.6 CHEMICAL REACTIONS

6.6.1 General

There are three types of chemical reactions being considered in this chapter. Each of these are used to treat various chemicals as specified in Chapter 4. In general, the wastewater is pumped into a tank, the treatment chemical or chemicals added to a predetermined endpoint, the system allowed to react and then the treated water is removed. The three types of reactions considered are neutralization, precipitation and oxidation/reduction.

To determine the amount of chemicals needed, bench testing operations are necessary. These involve small scale chemical addition to a sample of the actual wastewater. The volume of chemical needed to treat the entire spill and other operating parameters can then be established. After the chemical requirements are established, the process tankage required is calculated using procedures similar to those for gravity sedimentation. However, neutralization and oxidation/reduction reactions do not produce significant amounts of sludge and therefore, are easier to handle.

This section has been split into sub-sections to deal separately with the different types of chemical reactions up to and including the sub-section on design considerations. However, the construction details and operation and maintenance procedures have been combined because of the similarities in all of the chemical reaction procedures. Information on chemical injection, mixing and flocculation procedures have also been presented there.

6.6.2 Process Description: Neutralization

Neutralization is a process in which hydroxyl or hydrogen ions are added to a solution to produce an approximately equal concentration or a pH of 7. This process is used to reduce the acidic character of a spilled chemical by addition of caustic soda ($NaOH$), lime (CaO) or slaked lime ($Ca(OH)_2$) or soda ash (Na_2CO_3). Alkaline wastewaters ($pH>9$) are neutralized by the addition of hydrochloric acid (HCl), sulfuric acid (H_2SO_4) and acetic acid (HCH_3COOH).

The specific reagents to be added are indicated on the actual flow scheme in Chapter 4. Strongly basic, $NaOH$, or strongly acidic, H_2SO_4 and HCl, chemicals must be added very carefully to avoid creating a violent reaction. Complete mixing of the contents is especially important to avoid pockets of strong chemicals in the tank. The other reagents are considered weaker acids (acetic) and bases,(lime and sodium carbonate (soda ash)). In some schemes, acids used may be interchangeable with others and the choice is established by acceptable anion concentrations in the discharge. Any discharge restrictions for chloride, sulfate, or acetate ions should be established before the reagents are used. In general, strong reagents react faster than others. Lime has a relatively slow reaction rate and should be slaked with water before use. Even after slaking, the reaction time should be extended.

To establish the amount of neutralizing chemical needed, a bench scale test is performed. The endpoint of the reaction is a change in the pH to the desired or required level, generally pH 6-9. The diluted chemicals are added to a sample of the actual wastewater and then the required amounts are scaled up to allow both ordering of chemicals and treatment of the individual batches.

Generally, a 10 minute complete mix has been found to be satisfactory in field operation, however, addition of lime may require 15-30 minutes to stabilize and this extra time must be allowed.

6.6.3 Bench Testing Procedure - Neutralization

Equipment needed:

1. Beaker (preferable 500-1,000 ml).
2. Burette or graduated pipette.
3. Burette stand or pipette bulb.
4. pH meter or pH paper.
5. Mixing apparatus.
6. Graduated cylinder = 1/2 volume beaker.

Chemicals needed:

1. Acidic wastewater
    - a. slaked lime slurry - 100 mg/ml as CaO
    - b. 100 mg/ml $NaOH$ (sodium hydroxide).
    - c. 100 mg/ml Na_2CO_3 (sodium carbonate)
2. Alkaline wastewater
    - a. 100 mg/ml HCl
    - b. 50 mg/ml H_2SO_4
    - c. 100 mg/ml CH_3COOH

Procedure:

1. Place known volume of wastewater into a beaker two times its size.

2. Mix and record initial pH.

3. Add neutralizing chemical in increments and record volume added and pH after equilibrium has been reached (lime requires a longer time to reach equilibrium).

4. Continue adding neutralizing chemicals to reach pH 4 or pH 10.

5. Plot neutralization curve, pH versus amount of chemical/liter of wastewater.

6. Choose desired pH, (usually 7) and corresponding dosage.

7. Repeat steps 1 and 2 and then add the amount of chemical required to achieve desired pH (usually 7).

8. Record time required to achieve final pH, note volume of any accumulated sludge.

Calculations for Neutralization Test:

1. Calculate the amount of chemical required per gallon of wastewater (see Section 7.8) and for entire spill.

2. Estimate the amount of time required per batch (see Table 28).

3. Calculate volumes of sludge produced per gallon of wastewater (if any).

$$\text{Volume of sludge} = \frac{\text{volume sludge}}{\text{volume test sample}} \times \text{volume of wastewater to be treated.}$$

TABLE 28. CHEMICAL REACTION OPERATING PARAMETERS

Process	Mixing		Endpoint	Chemicals
	Type	Time		
Chemical Sedimentation	Rapid Flocculation None	1-5 min 5-15 min 30-60 min depends on rate and process height	Clarified water and good settling	Ferric Chloride Aluminum Sulfate Polyelectrolytes
Neutralization	Rapid	10-30 min Use 30 min for lime addition	Add to pH 7, use pH paper or meter to check	Calcium Hydroxide, Calcium Oxide, Sodium Hydroxide, Sodium Carbonate, Sulfuric Acid, Acetic Acid, Hydrochloric Acid
Precipitation	Rapid Flocculation None	1-5 min 5-10 min 30-60 min depends on rate and process height	Varies to a pH or until residual of reactant or until clarified	Calcium Hydroxide, Sodium Hydroxide, Sodium Carbonate, Sodium Bicarbonate, Sodium Sulfate, Sodium Sulfide, Potassium Chloride
Oxidation Chlorination	Rapid	10-30 min	To a HOCl residual of 1 mg/l	Sodium Hypochlorite
Aeration	Air mix	depends on test	D.O. measure to 70% of saturation or other	Air
Reduction	Rapid	10-30 min	Large ORP change/ $Cr^{+6} \rightarrow Cr^{+3}$ is yellow to green HOCl reduction, no Chlorine residual	Sodium Bisulfite, Sodium Sulfide

6.6.4 Process Description: Precipitation

Precipitation is a process which removes pollutants by reacting these materials to form an insoluble product (51). This process results in a reaction rather than physical adsorption and is therefore different from coagulation and sedimentation, however, treatment construction is similar. There are a series of steps to allow effective precipitation: 1. chemical addition; 2. rapid mix; 3. addition of coagulant; 4. flocculation; 5. sedimentation; and 6. filtration. However, each precipitation reaction may not require all of these processes and secondly all of these steps except filtration can be performed in one tank.

Precipitation is used to remove many types of metal cations and some anions such as fluorides and sulfides. The reagents involved in the precipitation reactions include calcium and sodium hydroxide and sodium carbonate, bicarbonate, sulfate and sulfide. These chemicals are added to reach certain pH or in some cases to a small residual of the reagent. Sulfide amount and addition can be checked using an electrode or by reacting with zinc acetate. The sulfide residual is present when a white precipitate appears or if zinc acetate indicating paper changes color. However, excessive sulfide addition must be avoided because of the strong reducing ability of this material. The other precipitation chemicals (e.g., lime, soda ash) are added to a specific pH, allowed to mix and then to settle. If no definitive test is available, the addition of a reactant to a distinct floc, and then analysis of the supernatant for the contaminant is necessary. However, the metallic hydroxides are difficult to remove so coagulation and flocculation using alum, ferric chloride or polymers (or a combination) may be helpful. The procedure to establish chemical dosages of the coagulant is the same as that outlined in the gravity sedimentation section.

The amounts of chemicals required to precipitate the entire reactant are determined by running a bench scale test. This test is similar to the procedures outlined earlier in Section 6.5. A known volume of wastewater sample is reacted to the endpoints specified in the treatment specifications from section 6.5.2. The chemicals are mixed, reacted and then settled. If necessary a coagulant is added to improve the settling. Once the test is completed, the data is scaled up to determine the amount of chemical required. In general, 25% excess chemical should be ordered.

When operating a field unit, the tank contents should be mixed completely for 5-10 minutes (or 15-30 minutes if lime is added). If flocculation is required, a 10-15 minute flocculation at a speed just fast enough to keep the solids suspended is required: the settling time will be equal to

$$\left[\frac{\text{height of tank m}}{\text{settling rate m/min}}\right] \times (2\text{-}3)$$

The 2-3 is the scaleup factor for most settling operations.

6.6.5 Bench Testing Procedure: Precipitation

Equipment needed:

1. Beaker (preferable 500-1500 ml).
2. Graduated cylinder (1/2 volume of beaker).
3. Burette or graduated pipette (pipette is better for lime addition).
4. Burette stand or pipette bulb.
5. pH meter, or pH paper, or chemical testing kit, or zinc acetate paper, or zinc acetate
6. Mixing apparatus.
7. 1,000 ml graduated cylinder.
8. Stop watch or watch with second hand.

Chemicals needed:

1. lime (calcium hydroxide) $Ca(OH)_2$.
2. Sodium hydroxide NaOH.
3. Sodium carbonate Na_2CO_3.
4. Sodium bicarbonate $NaHCO_3$.
5. Sodium sulfate Na_2SO_4.
6. Sodium sulfide Na_2S.
7. Coagulants
    - a. ferric chloride.
    - b. aluminum sulfate.
    - c. polyelectrolytes.
8. Sulfucic acid (H_2SO_4) may be needed.

Procedure:

1. Place known volume of wastewater into beaker two times its size.
2. Mix/record initial pH.
3. Add acid to adjust pH if necessary.

4. Add reagents (as indicated) in increments and record pH until the desired pH level is reached while mixing for 2 minutes. If pH is not the controlling factor as for sulfate:

   Take samples at increments after mixing and analyze for sulfate concentration using Hach kit or spectrophotometer.

   For sulfide:

   Take samples at increments after mixing and analyze for sulfide concentration using a $S^{=}$ probe or precipitation with zinc acetate (paper or chemical).

   For others:

   Add chemical until a good floc is formed.

5. Allow to settle and note the rate of settling using a stopwatch and increments on the beaker.

6. Take sample of supernatant for analysis of contaminant.

7. Plot pH versus volume of reagent added/liter of waste, sulfate/sulfide residual versus volume of reagent added/liter of waste or concentration of contaminant versus volume of reagent added.

8. Choose point on curve to establish amount of reactant needed.

9. Place another wastewater sample into 1 liter and add chemical while mixing.

10. Check to insure endpoint has been reached.

11. If the settling is poor, add coagulants in the amounts indicated in the previous section and establish a new settling rate (section 6.5.2).

12. Note sludge volume and height in the cylinder.

Calculations from Data:

1. Scale up the results to establish the amount of chemical required per volume of wastewater to be treated.

2. Calculate amount of sludge expected per volume of wastewater.

3. Calculate the amount of time needed for entire reaction (see Table 28).

6.6.6 Process Description: Oxidation/Reduction

Oxidation/reduction involve the transfer of electrons from one species to anogher. Oxidation involves the loss of electrons and reduction, the gain of electrons. In some instances these reactions can be used to change hazardous species into less harmful forms.

Reduction: In this manual, reduction reactions are only applicable to a small number of compounds. Sodium bisulfite has been recommended as the reducing agent, however, other chemicals including sodium sulfite and sodium metabisulfite can also be used. Reduction is used as a pretreatment for chromate or chromyl compounds to change them to the chromic state for precipitation. This reaction must occur at low pH, so adjustment to pH 2-3 with acid is recommended. The endpoint is best determined by either a large oxidation reduction potential (ORP) change, as measured by a platinum electrode, or removal of the chromate (e.g. Cr^{+6}) as measured by a chemical test. A visual indication is the color change from yellow to green and it can be used as a confirming indicator. Reduction is also used when either sodium or calcium hypochlorite are to be removed. The pH is reduced to three and the reducing agent can be added until an acceptable chlorine residual is measured. Excess reducing agent can be removed by addition of more wastewater or aeration.

To determine the amount of sodium bisulfite, or its equivalent, to order, a small scale bench testing procedure is used. A known volume of wastewater is placed in a beaker and the reagents are added to the endpoints indicated in the treatment specifications. The reaction time and any sludge volume should be noted by the OSC.

Once the amount of chemical required has been established, the chemicals should be ordered from suppliers. In operating a large scale reduction process, the acid should be added (75%, then in increments) and mixed approximately one to two minutes and the pH should be determined. Then the bisulfite can be added to the pre-established endpoint, in the same manner, e.g., add 75% of the total and then increments until the endpoint is reached. The tank should then be mixed for ten minutes to insure complete reaction and then the residual rechecked for discharge.

Oxidation: Oxidation reactions are more common than reduction and more reagents can be used. Chlorination and aeration are two ways to oxidize materials. Chlorination is discussed here and aeration is addressed in a later section.

Chlorination reactions are most commonly used to oxidize cyanide to the less toxic cyanate and then to carbon dioxide and nitrogen. These reactions are most effective at alkaline pH so soduim hydroxide is often added with hypochlorite. The chlorine is most safely added in the form of liquid hypochlorite in concentrations of 5%-6% (household bleach). On a bench scale the concentration is diluted tenfold or more. Chlorine doses are determined by doing a bench scale test until a slight residual of chlorine remains as measured by a test kit. Once operating in the field, both NaOH and hypochlorite should be added at 75% of the expected volume and then in increments to the desired endpoint. The system should then be mixed and additional 15 minutes and the residual chlorine tested before discharge to be certain it meets acceptable limits.

6.6.7 Bench Test Procedure - Reduction

Equipment needed:

1. Beaker (500-1500 ml).
2. Graduated cylinder (1/2 volume of beaker).
3. Burette or graduated pipette.
4. Burette stand or pipette bulb.
5. pH paper or meter.
6. ORP meter, chemical test kit or swimming pool test kit.
7. Mixing apparatus.

Chemicals needed:

1. Sulfuric acid H_2SO_4.
2. Sodium bisulfite.

Procedure:

1. Place known volume of wastewater into beaker two times its size.
2. Mix/record initial pH.
3. Add acid to pH 2-3.
4. Add sodium bisulfite to
    a. large ORP change
    b. removal of chromate (CR^{+6})

5. React ten minutes.

6. Scale up to establish amounts of reagents needed.

6.6.8 Bench Test Procedure: Chlorination

Equipment Required:

1. Beaker (500-1500 ml).
2. Graduated cylinder (1/2 volume of beaker).
3. Burette or graduated piputte.
4. Burette stand or pipette bulb.
5. pH meter or pH paper.
6. Chlorine test kit (Hach, swimming pool).
7. Mixing apparatus.

Chemicals needed:

1. Sodium hydroxide-NaOH.
2. Hypochlorite solution.

Procedure:

1. Place known volume of wastewater into beaker two times its volume.
2. Mix/record initial pH.
3. Add NaOH to desired pH.
4. Add chlorine in increments mix and check residual.
5. Stop adding chlorine when residual appears.
6. Allow to mix five minutes, check residual.
7. Add more chlorine if necessary to reach a persistent residual.
8. Note any sludge produced.
9. Scale up to the amount of hypochlorite required to treat entire spill.

6.6.9 Design of Chemical Reaction Processes

1. Calculate amounts and order chemicals from the manufacturer (see Section 7.9 for information).

   Explanation: Chemicals will require long delivery times and should be ordered immediately. If the total amount of chemical is not available immediately, have a partial order shipped first.

2. Design the volume of chemical tanks needed to hold one day's supply of chemicals.

   a. Calculate volume of chemicals needed per day:

   $$\frac{\text{volume of feed solution}}{\text{day}} = \frac{\text{volume of feed solution}}{\text{volume of wastewater}} \times \frac{\text{volume of wastewater}}{\text{day}}$$

   b. Calculate size of tanks needed per day:

   $$\text{volume of tank} = \frac{1.2 \times \text{volume of feed solution chemicals}}{\text{day}}$$

   c. Determine if single or multiple feed tanks are needed.

   Explanation: If large volume of chemicals are needed daily, a smaller feed tank can be used with a seperate mixing tank. Chemicals can be mixed in batches throughout the day to provide a supply for the feed tank.

   d. Repeat steps (a-c) for each chemical.

3. Apply data from bench tests to establish a detention time.

   Explanation: Refer to Table 28 for general reaction times. Follow calculations when settling is necessary

   $$\text{Detention time} = \frac{\text{process height}}{\text{settling rate}} \times 3$$

   Example: Refer to section 6.5.4 for an example of the calculations.

4. Choose a tank type using the following criteria (Section 7.3):

   a. The shallower the tank the shorter the total time needed for settling, when necessary. Also, mixing gradients may be more effective. All depths should be greater than 0.91m (3 ft) with at least 0.305m (12") of freeboard.

b. Choose a desludging technique if precipitation or chemically treated sedimentation is used. Refer to section 6.5.4 for information on desludging techniques.

5. Calculate the process volume per tank according to the formulas presented in Figure 73.

6. Calculate fill and draw times.

$$t_{fill} = t_{draw} = \frac{Vn}{\text{pump rate}} = \frac{Vn}{Qn}$$

Explanation: Process flow rate has been previously established using limiting factors design (see Section 5.4).

7. Calculate total time of tank use per batch.

$$T_T = \text{total time} = 2\ (t_{fill}) + t_d\ (\text{detention time})$$

Explanation: t_{fill} is calculated from Step 6.

8. Establish the frequency of desludging.

$$\text{time between desludging} = \frac{0.25 \times H_p \times T_T}{\frac{\text{accumulation of sludge}}{\text{batch}}}$$

Explanation: Desludging must be done when the sludge accumulates to 1/4 of the available process height. Sludge will accumulate considerably in the precipitation reactions or chemically treated sedimentation. Oxidation/reduction and neutralization reactions should not generate much, if any, sludge. Therefore, if sludge accumulation is negligible, Steps 8-9 can be eliminated.

$$\frac{\text{Accumulation of sludge}}{\text{batch}} = \frac{\text{height of sludge in test}}{\text{height of liquid in test}} \times \text{process height}$$

9. Calculate the effective tank volume. (Volume is reduced by sludge accumulation).

$$\frac{\text{amount of sludge accumulation}}{\text{between desludging}} = \frac{\text{amount of sludge}}{\text{batch}} \times \frac{\text{batches}}{\text{before desludging}}$$

$$\text{batches between desludging} = \frac{\text{time between desludging}}{\text{time per batch}}$$

Calculate new effective volume

$$V_n \text{ eff} = \frac{\pi D^2}{4} \times \text{effective depth} = 0.78\ D^2 \times \text{effective depth.}$$

10. Calculate process volume required.

$$V_p = Q_p\ (T_T)$$

Explanation: Q_p or system flow rate is already established.

11. Calculate number of tanks needed.

$$n = \frac{V_p}{V_n \text{ eff}}$$

Explanation: Always round n to the higher round number.

12. Calculate the sludge volume accumulated per day.

$$\frac{\text{sludge volume}}{\text{day}} =$$

$$\left(\frac{\text{height of sludge}}{\text{per batch}} \times \frac{2 \times \text{number of batches}}{\text{day}} \times 0.78\ D^2\right)$$

Explanation: It is assumed that the sludge is disposed of once per day and the tanks are cleaned for the following day.

13. Calculate the number of sludge tanks needed.

$$n_{sl} = \frac{\text{sludge volume/day}}{\text{volume of 1 tank}}$$

Explanation: It is assumed that the sludge disposed of once per day and the tanks are cleaned for the following day.

14. Calculate the capacity required for each rapid mix tank.

$$V_{RM} = 5 \times Q_p \xrightarrow{\text{to}} 10 \times Q_p$$

Q_p = process flow rate from Section 5.4

Explanation: The rapid mix tank will be designed on a continuous flowthrough basis with a detention time from 5-10 minutes. One tank will be necessary for each process tank.

15. Choose rapid mix tank type from Section 7.3 following these guidelines.

    1. Sturdy construction.
    2. Compatible materials for chemicals being added.
    3. Height to diameter ratio 0.5-1.5 if possible.

6.6.10 Construction of Chemical Reaction Processes

Two separate systems are described here to accomplish the various chemical reaction requirements; aeration processes are discussed separately.

A. Chemical addition and mixing.
B. Chemical addition, mixing and flocculation.

A. Chemical Addition and Mixing - This option is used for the addition and mixing of one or more chemicals in a continuous flow rapid mixing tank followed by chemical reaction to a predetermined endpoint in a batch operated tank. A schematic diagram of the system is shown in Figure 64. Construction details follow.

1. Install rapid mix tank as instructed in Section 7.3.

    a. Construction of submerged jet (Figure 65) for the process flow transfer pump (52).

        Explanation: Recommended for most mixing conditions, although the faster mixing chemicals will be properly mixed from the normal transfer hose discharge velocities.

        Principle of operation - When a submerged jet is introduced into a tank, the jet stream traverses a significant distance through the water before the jet stream velocity dissipates. The jet tends to entrain fluid, producing significant mixing and the creation of a turbulent zone.

        1) A nozzle can be constructed by installing a combination nipple into the hose end of transfer pumps 1 and 2 and bushing it down to the desired jet diameter, D_j (see Figure 65).

            Explanation: Commercially available tank eductors may also be used; they have a shroud around the nozzle to increase entrainment and intensity of the turbulence.

            Jet diameter will depend on tank configuration and detention time

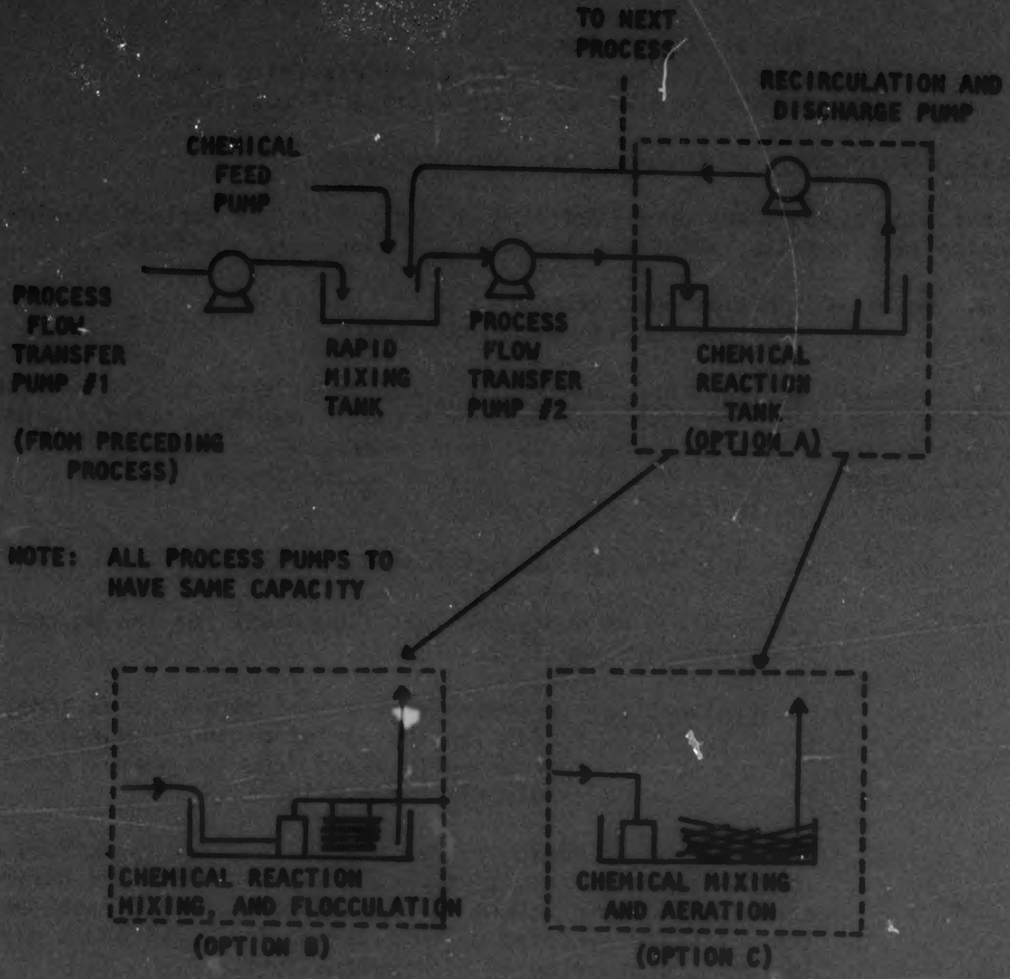

TO NEXT PROCESS
RECIRCULATION AND DISCHARGE PUMP
CHEMICAL FEED PUMP
PROCESS FLOW TRANSFER PUMP #1
(FROM PRECEDING PROCESS)
RAPID MIXING TANK
PROCESS FLOW TRANSFER PUMP #2
CHEMICAL REACTION TANK (OPTION A)
NOTE: ALL PROCESS PUMPS TO HAVE SAME CAPACITY
CHEMICAL REACTION MIXING, AND FLOCCULATION
(OPTION B)
CHEMICAL MIXING AND AERATION
(OPTION C)

Figure 64. Schematic diagrams of chemical treatment options.

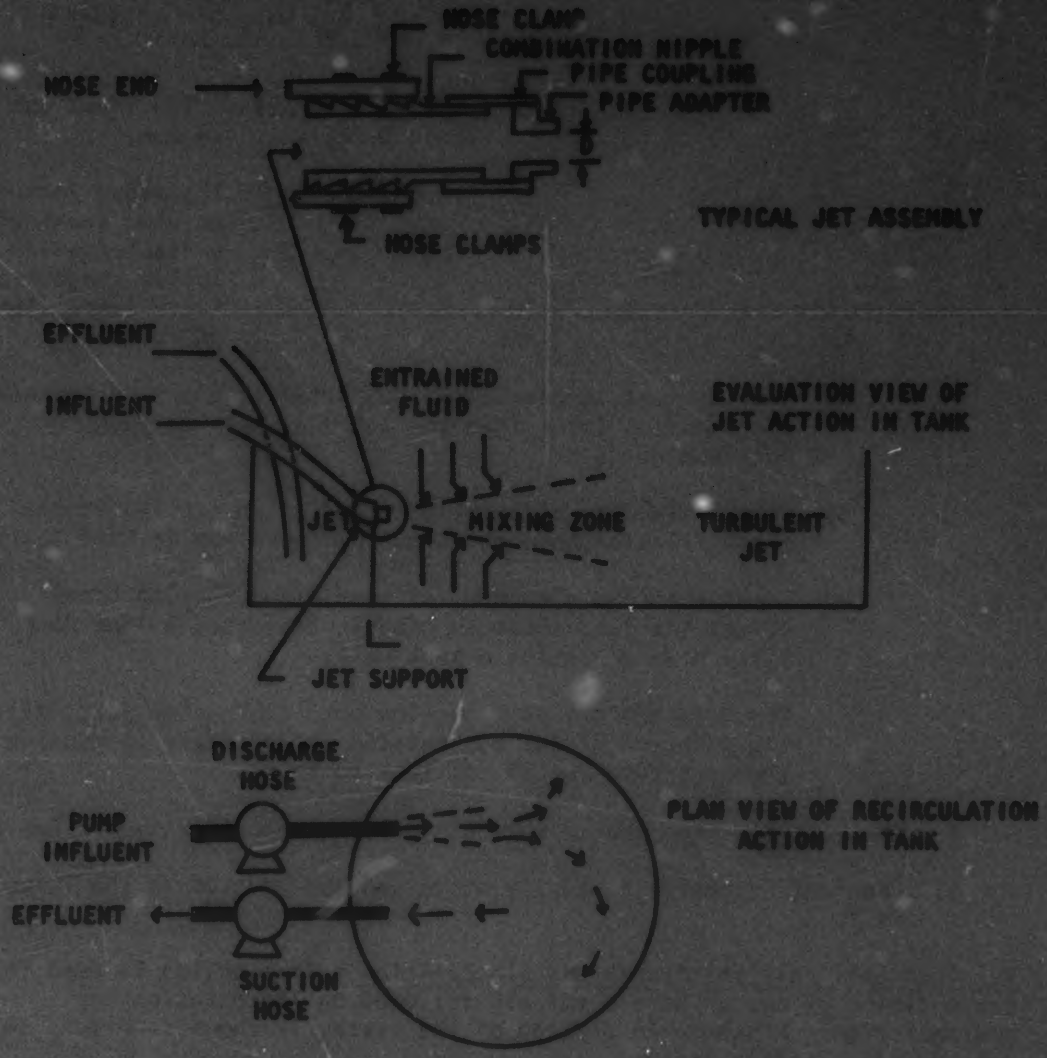

HOSE CLAMP
COMBINATION NIPPLE
PIPE COUPLING
PIPE ADAPTER
HOSE END
HOSE CLAMPS
TYPICAL JET ASSEMBLY
EFFLUENT
INFLUENT
ENTRAINED FLUID
EVALUATION VIEW OF JET ACTION IN TANK
JET
MIXING ZONE
TURBULENT JET
JET SUPPORT
DISCHARGE HOSE
PUMP INFLUENT
PLAN VIEW OF RECIRCULATION ACTION IN TANK
EFFLUENT
SUCTION HOSE

Figure 65. Installation of jet mixer in rapid mix tank.

and so it is desirable to obtain bushings in the size range calculated below and basing the final selection on a trial basis (52)

$$D_J = \sqrt{\frac{Q_p}{7}} \text{ to } \sqrt{\frac{Q_p}{20}} \quad \text{(inches)}$$

where Qp = process flow (gpm) gpm gpm x 3.785 x 10^{-3} = cum.

Explanation: The above formula will provide a discharge velocity range from 6.1-9.1 mps (20-30 fps).

2) The jet must be adequately supported in the tank because the reaction force from the jet will tend to push the hose backwards.

3) When sizing the effluent pump add 21.3m (70 ft) to the total friction head to account for the nozzle head loss.

4) Guidelines for placement of nozzle and suction hose: Orient the jet stream so that it traverses a long distance before hitting a tank wall.

Position the effluent suction hose behind the jet. Alter the location of jet and suction as necessary to achieve thorough turnover of the tank contents.

2. Chemical reaction tank - same as construction of sedimentation tank

3. Chemical injection - usually submerged and located in the inlet well.

B. Chemical Addition, Mixing and Flocculation - This option is used for the addition of one or more chemicals followed by flocculation and sedimentation. A schematic diagram of the system is shown in Figure 66. Construction details follow.

1. Rapid Mixing Tank - Identical to construction option A, Steps 1-2.

2. Construction of Flocculation Tanks (Figure 66) - Tank sizing has already occurred as part of the design process in Section 6.5.5. The remaining construction steps involve flocculator construction, inlet well, and outlet baffle.

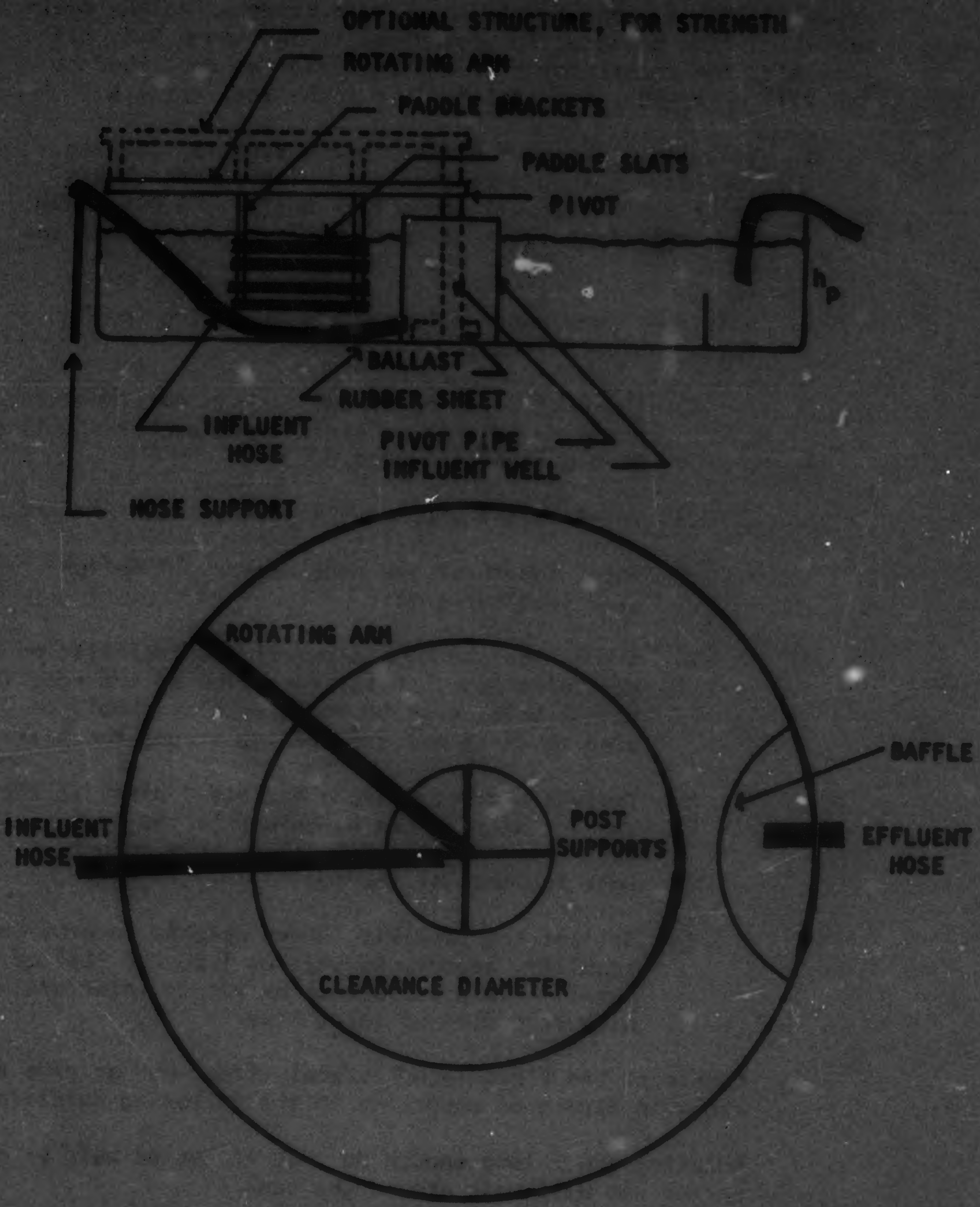

OPTIONAL STRUCTURE, FOR STRENGTH
ROTATING ARM
PADDLE BRACKETS
PADDLE SLATS
PIVOT
h_p
BALLAST
RUBBER SHEET
INFLUENT HOSE
PIVOT PIPE
INFLUENT WELL
HOSE SUPPORT
ROTATING ARM
BAFFLE
INFLUENT HOSE
POST SUPPORTS
EFFLUENT HOSE
CLEARANCE DIAMETER

Figure 66. Construction of a mechanical flocculator.

The gentle rolling action necessary for flocculation requires a minimum of fluid shear to disrupt the floc. It can be produced with a canoe paddle in certain cases using the sedimentation tank construction described in Section 6.5.5. If possible, the construction of a flocculator as described below will give much more satisfactory mechanical results.

a. Tank Installation - A flat bottom tank is required. Tank liners should be protected with rubber sheets under the inlet well and outlet baffle. A 0.9-1.22m (3-4 ft) clear space is needed all the way around the tank.

b. Obtain or construct an inlet well according to the following guidelines.

   1) The configuration of the tank is not important provided that it be sturdy (preferably steel) and have a level top edge.

   2) Total height approx. 3/4 process water height.

   3) Total length of top edge approx 0.336m/lpm (1/2 inch per gpm).

   4) A hole must be cut to permit the installation of the inlet hose. After insertion of the hose into the hole, rags or other packing should be used to close off the opening around the hose.

   5) Install a pivot post, e.g., steel pipe, in the tank. The pipe can be welded to the tank bottom and supported by three bars to act as post supports at the top.

   6) Ballast the tank with heavy weights to provide stability approx. 45.5-91 kg (100-200 lbs) of metal. Place ballast so as not to interfere with free flow of inlet hose.

c. Construct the Flocculator Assembly from wood or pipe as shown in Figure 66 according to the following guidelines.

   Rotating arm - long enough so that it can be held by a person who will walk around the tank.

   Pivot - very solidly joined to rotating arm and extending down about six inches into the pivot pipe.

Paddle Brackets - very solidly attached to rotating arm and mounting the paddle slats.

Note: Especially in wooden construction, it may be desirable to use a two-arm construction which would reduce the stress at the high stress points (shown with astericks on Figure 66).

Paddle Slats - About four are necessary with spaces in between. Top slat should be submerged; bottom slat at a height of one-third the process height; and inside and outside rotational diameters to clear the inlet well, outlet baffle, and inlet hose.

d. Construct an outlet baffle and serrate the end of the outlet hose as described in Section 6.5.5, Steps A, 3-4.

6.6.11 Operation and Maintenance of Chemical Reaction Processes

The mode of operation for all chemical reaction processes is batch operation with end point control. Prior to giving explicit operational instructions for each of the three design options described previously, the steps necessary to produce end point control will be outlined. However, prior to any operation, the treatment chemicals must be mixed to the proper feed concentrations. Instructions are included in this section.

Step 1: Mixing the chemicals into the desired feed concentrations.

a. Calculate the amount of water needed to dilute the concentrated chemical (Section 7.8.2).

b. Add water to the chemical tank and agitate using an impeller mixer (Section 7.5).

c. Follow any specific instructions for mixing listed in the chemical data sheets (Section 7.8.3).

d. If no special instructions are given, follow these procedures:

Solids - Slowly drop powder or pellets into the swirling water and mix until dissolved or in suspension. Add more chemical until the entire amount has been added. If a lime slurry is being prepared, continue mixing throughout the entire operating period. Take precautions to avoid breathing dust or directly touching the chemicals.

Liquids - Pump the concentrated liquid slowly into the tank using a chemical feed pump. Mix thoroughly, continue adding liquid until the entire amount has been added. Avoid fast addition which could result in the evolution of large amounts of heat.

Step 2: Endpoint Measurement - In order to accurately measure the reaction completion, the endpoint must be measured during the actual treatment of the system. The efficiency is also a function of the effective mixture of the contents. The amount of chemical expected to be used per batch is first calculated, 75% is added during the influent flow and the remainder is added in increments to the endpoint.

a. Calculate the amount of chemical needed/batch.

$$\frac{\text{volume of feed solution needed}}{\text{volume of wastewater batch}} = \frac{\dfrac{\text{volume of batch chemical added from bench test}}{\text{volume of wastewater}} \times \text{conc. of bench scale chemical}}{\text{concentration of feed solution}}$$

$$\frac{\text{volume of feed solution}}{\text{volume of wastewater}} =$$

$$\frac{\text{volume of feed solution}}{\text{volume of wastewater}} / \times \frac{\text{volume of wastewater}}{\text{batch}}$$

Example: Add 25 ml of 1N H_2SO_4 to 500 mls of sample. Volume of process tank is 37.8 cum or (10,000) gal. Use H_2SO_4 at 25% strength or about 9 N.

$$\frac{25\text{ ml}}{500\text{ ml}} \times \frac{1\text{N}}{9\text{N}} = 0.0055\text{ml 9N/ml sample}$$

Metric: 0.0055 x 37.8 cum = 0.201 cum of feed H_2SO_4.

English: 0.055 x 10,000 gal./batch = 55.5 gal. of feed H_2SO_4

b. Determine and collect endpoint measuring apparatus.

Explanation: The endpoint device may be a pH meter, portable chemical analysis kit, ORP meter, zinc acetate paper or other specific indicator. The faster the response the better.

c. Add 75% of the calculated volume during the tank filling operation.

Explanation: Calculate amount to add (Step a). Use 75% of the chemical to avoid overruning the endpoint. After the first batch, use 75% of the amount added to the preceding batch as the starting point. Since the strength of the wastewater will vary throughout treatment, this procedure provides an extra safety precaution.

Step d - Allow tank to mix.

Step e - Check endpoint of reaction at various points in the tank.

Explanation: This procedure will allow the operator to check the thoroughness of mixing and will allow determination of the endpoint. If the analyses give different results at different points in the tank, then further mixing is necessary.

Step f - Add more chemical in increments to reach the final endpoint (again check the endpoint at various places within the tank to insure complete mixing).

Step g - If more than one chemical is added; add the second chemical after the first following the same procedure except using induced recirculating mixing.

Step h - If flocculation is needed, it should begin after the mixing is completed.

Step i - When the final point is reached, mixing can be continued for the specific reaction period and then terminated and pumpout commenced.

Step 3: Chemical Addition and Mixing-- All Options: At the starting point in the process, the rapid mixing tank is about 2/3 full and the chemical reaction tank is drawn down as far as possible to the sludge layer.

Step a - Turn on the process flow transfer pump #1 and watch for jet nozzle action to begin in the rapid mixing tank.

Step b - Shortly thereafter, turn on process flow transfer pump #2 to pump at the same rate as pump #1.

Explanation: If the rapid mixing tank and the inlet well of the chemical reaction tank are at different levels, it may be necessary to withdraw the suction hose of Pump #2 between operations or to put a valve in the line to prevent syphoning. In that case, the hose must be repositioned or the valve opened before pump #2 can be started

Step c - As soon as the two pumps are running, turn on the chemical feed pump at a rate calculated by the following formula:

$$\text{feed rate (gph)} = \frac{\text{volume of feed solution (gallons)}}{60\ \frac{\text{min}}{\text{hr.}} \times \text{fill time (min)}}$$

gph × 3.785 = liters per hour

Caution: Do not fill the chemical reaction tank above the 0.305m (12 inch) freeboard height to provide a buffer zone to dilute the batch in the case where chemical reaction is carried out past the endpoint.

Step d - Turn off the chemical feed pump and process flow transfer pump #1 and immediately turn on the recirculation pump.

Step e - Through the process of monitoring and adding increments of chemicals, achieve endpoint conditions for chemical #1. Leave the recirculation pump and process flow transfer pump #2 running during the entire procedure.

Step f - If more chemicals are to be added, recalculate a new feed rate from the equation in Step 3.

Step g - Add this amount of chemical, monitor, and then achieve end point conditions as described in Step 5.

Step h - Further Process Steps - After chemical treatment is complete, the following processes may be performed before discharge of the reaction tank contents:

a. Gravity separation - operational procedures in Section 6.5.6

b. Flocculation and aeration - operation procedures described below.

Step i - Discharge the chemical reaction tank contents to the next process using the discharge pump.

Explanation: If the recirculation hose is used for discharge it will be necessary to remove the jet. It would be better to use a separate hose for discharge.

Flocculation - Operational Steps

Step a - with the recirculation pump off, the flocculator arm is moved through complete cycles around the tank to cause a gentle stirring action. If the tank contents begin to speed up in the direction of rotation, the rotation direction can be reversed to achieve more efficient mixing.

Step b - Continue flocculation until visual observations indicates that a good floc has formed (usually 10-15 minutes at longest).

Step c - Refer to sedimentation operational steps. Section 6.5.6

6.6.12 Chemical Reaction Troubleshooting

The most common problem would be that the endpoint is overshot. This will most likely occur at the beginning of operation before the kinetics of the reaction are familiar to the operators. When this situation occurs, the following procedure can be used.

1. Take a sample of the overtreated water.
2. Back titrate to the endpoint using contaminated water.
3. Note the volume of wastewater needed to reach the desired endpoint.
4. Scale up the results to determine the increased volume of wastewater to be added using the following formula.

$$\frac{\text{amount of wastewater to reach endpoint}}{\text{amount of overtreated water}} \times \text{volume of wastewater in process tank}$$

$$= \text{volume of wastewater to be added to process tank}$$

5. Extra freeboard 15cm (6") has been provided in the design to allow the additional wastewater to be pumped into the tank.

Other possible problems involved in chemical reactions include:

1. Concentration gradients in tank:	Check jet mixing systems to be sure they are operating properly.
2. Incomplete chemical reactions; after addition of entire chemical amount:	Repeat bench tests and recalculate required volumes. Also, if lime is used, allow system to react longer since the rate of reaction is slow.

6.6.13 Process Description: Aeration

Aeration is another method for oxidation. Air can be used as an oxidizing agent which is more available but not as strong as chlorine or chlorine compounds. In general, air is introduced into the tank at the bottom and the air bubbles rise to the surface. As they travel through the water column, the oxygen in the air is transferred through the bubble and into the water where it can react with the hazardous compound. However, this technique is only valuable for easily oxidized materials such as ferrous iron. Otherwise, lengthy reaction times would be necessary.

Aeration can also be used as a mixing technique, however, the necessity of placing manifolds near or on the tank bottom may preclude this method when sludge is accumulated. Another problem with using aeration for mixing occurs if the sludge layer is disturbed or if a reduction reaction is desired (the oxygen will be reduced before the hazardous compound). Therefore, aeration has only limited application as a mixing technique. When it is to be used, (e.g. for a neutralization system) the construction techniques will be the same as those applied in this section. Rates of aeration reactions are difficult to predict because a myriad of factors affect them. Among the variables which influence aeration rate are the following: manifold efficiency, blower efficiency, oxygen transfer rate, impurities in the wastewater, tank depth, temperature, humidity, etc. Therefore, a bench testing procedure is only used to establish a reaction endpoint and the feasibility of aeration with respect to time. The dissolved oxygen versus time can then be established by aerating a sample until it reaches the saturation point. From this data, an endpoint dissolved oxygen value can be chosen based on the desired efficiency of the reaction. Generally, a level of 70% of saturation can be considered the reaction endpoint. If the aeration reaction has required excessive amounts of time to reach completion, stronger oxidation may be needed. After the feasibility and the endpoint dissolved oxygen level have been established, one full sized reaction tank can be constructed. This procedure would allow the determination of the actual amount of time needed for field reaction. Then calculations regarding the number of tanks needed for field use can be made.

6.6.14 Testing Procedure: Aeration

Equipment needed:
1. ~ 5 gal pail
2. Diffuser stone
3. Air source
4. Dissolved Oxygen Probe
   or Burette/Burette stand/pipette/beaker/
   500 ml graduated cylinder
5. Stop watch
6. Thermometer
7. Barometer
8. Large graduated cylinder

Chemicals: Reagents for Winkler Titration.

Procedure:
1. Place known volume of wastewater into pail (~ 3/4 full)
2. Measure initial D.O.
3. Place diffuser stone in bottom and begin air flow
4. Measure D.O. at appropriate increments (varies from 30 sec - 15 min)
5. Keep measuring D.O. until saturation, i.e. no change in D.O. level

Calculation Procedure:
1. Plot the DO value versus time of aeration.
2. Choose a suitable endpoint DO value (usually 70% of saturation)

6.6.15 Design of Aeration System (see References 53-56)

The following design steps are necessary when designing a submerged header with orifices used in conjunction with an air compressor or blower.

Step 1 - Choose an available tank from Section 7.3 according to the following guidelines.

a. Use a flat bottom Type A tank, preferably 1.57-1.63m (62-64 in.) total height. Freeboard height should be 0.305m (12 inches) with a process height of 1.27-1.32m (50-52 inches).

b. Select a tank with a durable liner or else place a protective sheet within tank with thin plastic liners.

Step 2 - Determine the blower horsepower as a function of process volume, V , using Figure 67.

Explanation: The graph in Figure 67 was developed through use of the mixing formula:

$$G = \sqrt{\frac{P}{500 \mu V_p}}$$

Where P = mixing power, hp

G = velocity gradient, sec^{-1}

μ = dynamic viscosity of fluid, $lb\text{-}sec/ft^2$

Vp = process volume in ft^3

Because of the wide range of variables affecting this process, the use of the formula in preparing Figure 67 is based on the following assumptions:

G = 400, which is the flash mixing point (high rate mixing). This was used as a safety factor to be sure the blower is not undersized. In the actual case a lower velocity gradient will probably be sufficient.

μ = based on water only, more viscous substances would elevate this number and raise the pressure.

However, blowers may not be readily available and a compressor may have to be substituted even though it is not well suited for this

METRIC CONVERSIONS

gal. x 3.785×10^{-3} = liters
hp x 1.014 = hp (metric)
(°F - 32) 5/9 = °C

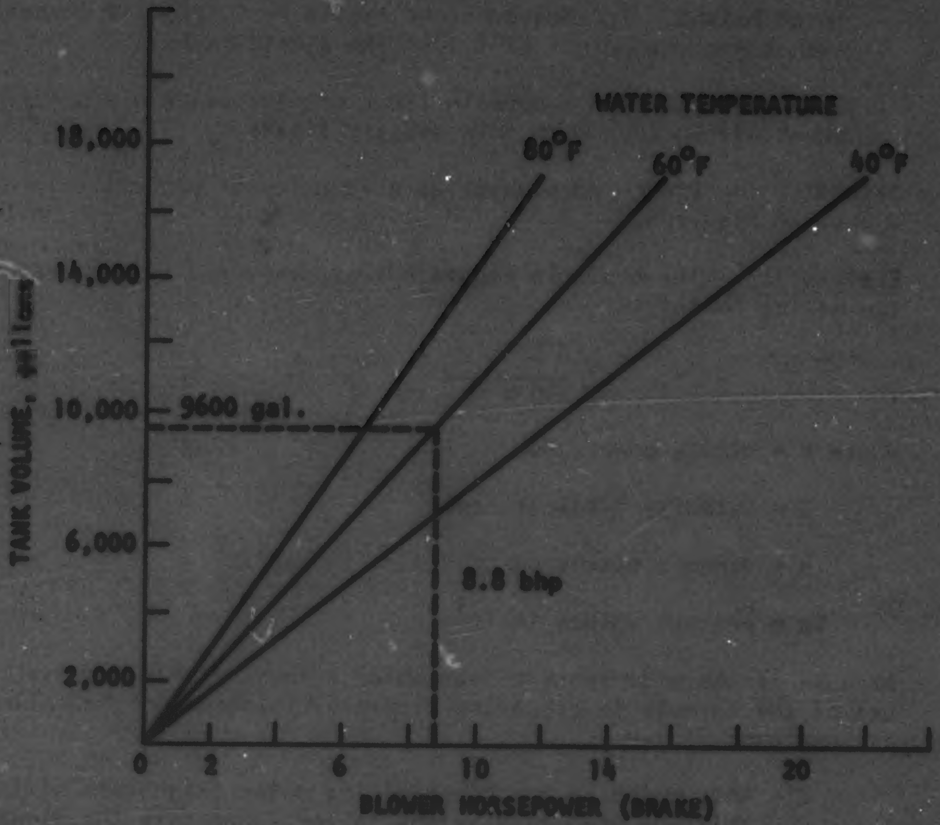


Figure 67. Blower size as a function of process volume for an aeration tank

application. The most readily available compressors will need a line regulator to reduce the pressure. Figure 67 does not apply to these high pressure compressors and the manufacturer should be consulted in the proper sizing for the application.

Example: A flat bottom tank with a process volume of 9,600 gallons is to be aerated. The water temperature will be around 60°F . From Figure 67 the required blower brake horsepower is 8.8 bhp.

gal. x 3.78 x 10^{-3} = cum

hp x 1.014 = hp (metric)

(°F - 32) x 5/9 = °C

Step 3 - Choose an available blower to provide the mixing horsepower at 5 psi of pressure.

Explanation: The low pressure nature of aeration make low pressure blowers, such as the positive displacement blower, the most suitable for this application. The major pressure losses which make up the .34 atm (5 psi) differential pressure are the following conversions: (psi x.0868 = atm).

1. Water head = the height of the water above the orifices, e.g., 36 inches x $\frac{1 \text{ psi}}{27.7 \text{ in}}$ = 1.3 psi.
2. Orifice loss = 0.5 to 2 psi through the potential flow range, Q (CFM) of aeration. (CFM x 0.47=liters per sec).
3. Line losses = valves, elbows, restrictions, etc., assumed to be less than 1 psi.
4. Safety factor = .7 to 2.2 psi to account for some of the variation which can result from temperature and viscosity changes, water height change, some plugging, etc.

Example: (same example as Step 2) A local supplier of positive displacement blowers has a blower that is rated from 2-12 psi and has the following ratings at 4 and 6 psi.

The following conversions are appropriate:

CFM x .472 = liters per sec.

psi x .068 = atm.

hp x 1.014 = hp (metric)

Air flow (CFM)		Brake horsepower (BHP)		Motor size (HP)	
4 psi	6 psi	4 psi	6 psi	4 psi	6 psi
211	227	5.3	8.4	7.5	10
350	394	8.8	13.9	10	15
554	536	16.5	21.9	20	25
731	694	17.9	25.6	20	30
1,106	1,041	27.2	37.1	30	40

It is necessary to interpolate this data. We are looking for a bhp rating at 5 psi equal to or greater than 8.8 bhp. Interpolation shows that the second line satisfies this condition at about 11 bhp and 370 CFM. This will require the 15 hp motor. This unit did not come with a variable speed drive and so a bypass valve was also acquired for flow control.

Step 3 - Determine total orifice area A_o according to the following formula:

$$A_o = \frac{Q}{80}\ (\text{in}^2) \qquad \text{in.}^2 \times 6.45 = \text{cm}^2$$

Where Q = blower air flow at 5 psi and mixing horsepower from Figure 67.

Explanation: This formula derives from the continuity equation, $Q = Av$, solved simultaneously with the orifice equation

$$\dot{v} = 1{,}096\ c\sqrt{\frac{\Delta P}{\rho}}$$

Where v = orifice velocity, fpm

c = orifice coefficient

Δp = differential pressure across the orifice (inches of water)

ρ = density of air (assumed to be .075lbs/ft^3 at standard conditions).

The differential pressure used to calculate the above formulae was just under 24 inches. Only about one foot would have been required, however, it is necessary that the pressure never go below six inches in the tank or there will be uneven aeration. The above formula for sizing the holes will permit a significant reduction in flow from design sizing before poor distribution will occur.

Example: From the previous example:

$$A_o = \frac{370\ \text{CFM}}{80} = 4.62\ \text{in}^2 \qquad (\text{inches})^2 \times 6.45 = \text{cm}^2$$

Step 4 - Design a header lateral system consisting of 15-20cm (6"-8") diameter pipe headers with 10 cm (4") diameter laterals connected as shown in the typical examples in Figure 68.

Note: When laying out the pipes, leave room in the tank for an inlet well and an outlet baffle as described in Section 6.5.5.

The following are criteria to be used in designing the header:

a. The 10 cm (4") dia. lateral pipes cover a good portion of the tank.

b. A minimum length of lateral should be used so that when 0.5 cm (3/16") to 1.3 cm (1/2") dia. holes are equally spaced along the laterals, the hole spacings are not closer than 10 cm (4") apart.

Example: The smaller the holes, the smaller the bubbles, which is good; however, the smaller the holes, the longer the required laterals, which may be prohibitive to construct. Good judgment is required.

Example: $$\frac{4.6\ \text{in}^2\ \text{of holes}}{.027\ \text{in}^2\ \text{per hole}} \times \frac{4\ \text{in}}{12\ \text{in/ft}} = 56.5\ \text{ft.}$$

for 3/16" holes

and

$$\frac{4.6\ \text{in}^2\ \text{of holes}}{.196\ \text{in}^2\ \text{per hole}} \times \frac{4\ \text{in}}{12\ \text{in/ft}} = 7.7\ \text{ft.}$$

for 1/2" holes

inches x 2.54 = cum
ft x .305 = m

c. Any cross distribution header should have at least two headers as shown in the C-, H-, and X- configurations in Figure 68.

6.6.16 Construction Steps: Aeration

Step 1 - Order a blower or blowers to provide the required air flow capacity at 5 psi. See Section 7.6 if a rotary screw air compressor is used. A pressure regulator is needed to reduce pressure from 60 psi down to required pressure. A bypass valve downstream of the pressure regulator will be needed for flow control.

Step 2 - The tank size and aeration header configuration have been established in the design section. The header may be constructed of rigid steel or plastic pipe.

Step 3 - Drill the holes for the orifices a minimum of 10 cm (4") apart in the top side of the laterals. Do not drill the main headers.

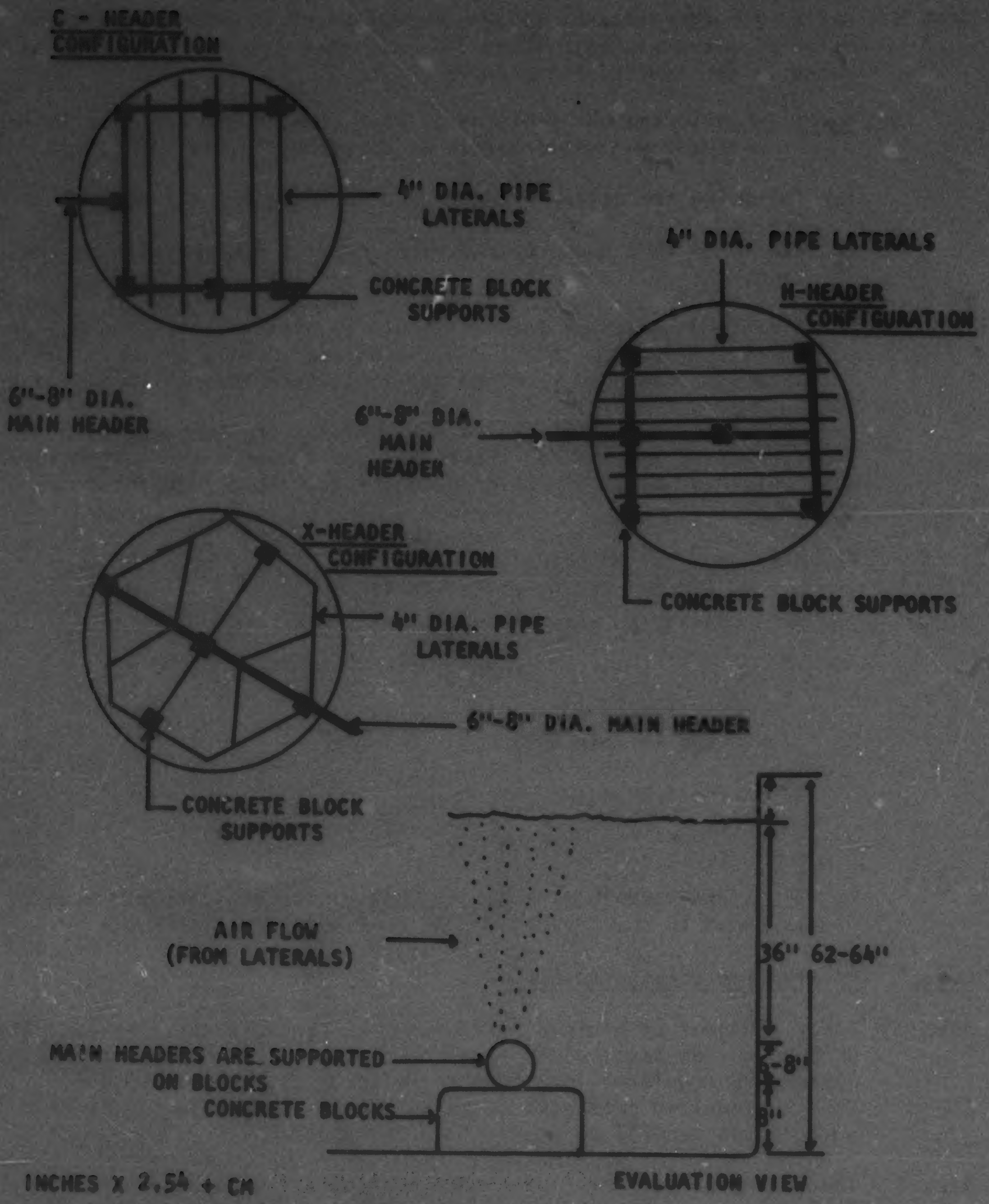

C - HEADER CONFIGURATION
4" DIA. PIPE LATERALS
CONCRETE BLOCK SUPPORTS
6"-8" DIA. MAIN HEADER
4" DIA. PIPE LATERALS
H-HEADER CONFIGURATION
6"-8" DIA. MAIN HEADER
CONCRETE BLOCK SUPPORTS
X-HEADER CONFIGURATION
4" DIA. PIPE LATERALS
6"-8" DIA. MAIN HEADER
CONCRETE BLOCK SUPPORTS
AIR FLOW (FROM LATERALS)
36"
62-64"
6-8"
8"
MAIN HEADERS ARE SUPPORTED ON BLOCKS
CONCRETE BLOCKS
INCHES X 2.54 = CM
EVALUATION VIEW

Figure 68. Aeration tank header alternative plan view layouts and schematic of header support

Step 4 - Place the header into the tank and support it on six to ten concrete blocks placed at positions as shown in Figure 68. Wire the header to the blocks.

Step 5 - Piping from the header to the compressor should be kept as short as possible. If a positive displacement blower is used no shutoff valves or other restrictions which could terminate flow may be used unless pressure relief is provided. In addition, a check valve is needed or other means of preventing backflow of water through siphoning.

6.6.17 Operation and Maintenance: Aeration

Aeration systems are also operated on the basis of endpoint control. Chemical reactions may take place either preceding or succeeding aeration using the same steps indicated in 6.6.13.

Aeration for oxidation can be done using the following procedure:

1. Pump contaminated water into the tank.
2. Start the compressor and begin air flow, slowly at first, using visual observation to determine proper air flow condition. Please note that when the blower is shutoff, the air header manifold fills with water (and debris). When the blower is turned on again the air must purge the lines. This requires higher than normal pressures. It would be desirable to refrain from shutting off the blower with a full tank unless absolutely necessary.
3. Monitor the dissolved oxygen at various parts of the tank.
4. Continue aeration until a stable dissolved oxygen endpoint is reached.
5. Pump contaminated water out of the process tank into the next process.
6. Desludge when the sludge layer reaches the top of the concrete blocks to avoid clogging lateral holes.

6.6.18 Troubleshooting Aeration

Aeration times may be excessive so the following possible solutions are presented:

Problem: Extremely long aeration times

Possible Solutions: 1) Clean holes in laterals; 2) Check for proper compressor operation; 3) Repeat bench tests to determine if endpoint has changed; 4) Check temperature and barometric pressure to determine if the saturation value has been reduced; 5) Determine if chlorination would be more effective oxidation method by consulting technical advisor.

7.0 CHAPTER 7 PROCESS COMPONENTS AND TREATMENT CHEMICALS

7.1 GENERAL

There are many components and materials which are common to all of the treatment unit processes. Therefore, to avoid unnecessary repetition, these components and selection criteria have been presented separately from the construction details. This separation will require the user to cross reference between Chapters 6 and 7 frequently. Therefore it is mandatory that the user be familiar with and understand the information presented in both sections to allow proper use of this Manual.

The information presented here is intended as a guide and basic reference on mechanical components. It is not a comprehensive review of all possible materials. The information presented has been abbreviated and simplified for use. Further information can be obtained from other references. When equipment choices are made by the user, it is advised that this choice be confirmed by equipment manufacturers or other specialists in this field.

It was determined that the components section be broken down into six parts. These parts are summarized as follows:

Process Pump - (sizing and selection)

Process Tanks - (volume calculations and types)

Hoses, Valving and Fittings - (types and applications)

Chemical Feed Components - (requirements)

Blowers and Compressors - (types and sizing)

Materials of Construction - (types and application)

7.2 PROCESS PUMPS

Field implementation of treatment processes will require the availability of pumps which are capable of moving the fluids under a variety of service conditions. Successful implementation demands that properly selected pumps be utilized to assure continuous operation and controllability of the process. Careful selection is necessary because no one pump can meet all service requirements and different pumps are available to meet different needs. Care must be taken not to misapply a pump or failure may result.

It is not possible to select a pump on flow requirements alone--other important operating variables will have to be considered before a final selection can be made, e.g., total dynamic head, suction conditions, viscosity, solids content, power source, mobility requirements, corrosivity, pumping explosive or flammable liquids, etc. The pump sizing and selection criteria presented here are condensed and conservative to permit selections without going through much of the detail normally involved in pump selections.

However it is not recommended to grossly oversize the pump, thus eliminating the necessity of performing sizing calculations. Oversizing is generally better than undersizing in emergency situations but with the drawback that pumps lose efficiency and are not as controllable when operated above or below their design ranges. Calculations of required flow and head permit the selection of a pump which can operate in its efficient range. It must also be carefully noted that the pump is not the only critical component in a properly designed pumping system. Other factors such as line sizes and flow restrictions, fittings, type of hose used, and the nature of the operation and the substances to be pumped can determine to a large degree the efficiency of the pumping system. A systems design approach, which takes these important variables into account, will give the designer substantial input concerning the nature of the system. This knowledge becomes invaluable when dealing with problems which may occur. With the exception of certain special pumping conditions such as the pumping of viscous fluids, heavy solids loadings, or flammable or explosive substances, pump selection may be made by first performing pump sizing (Section 7.2.1) and then turning to the pump selection section (Section 7.2.2). Special pumping situations are presented in Section 7.2.3.

7.2.1 Pump Sizing Procedure

The following procedure has been developed to assist in pump selection for typical fluid transfer operations as part of field implemented treatment systems. Assumptions are that the fluid is vapor-free, of low viscosity, and with medium solids content. Inlet and outlet conditions are assumed to be at ambient pressure and temperature conditions (57).

Step 1 - Calculation of System Flow Rate

Based on the volume of fluid to be transferred and the required transfer time, system flow rate is calculated as follows:

$Q_s = \frac{V}{t}$ where Q_s = system flow rate, $\frac{m^3}{min}$ (gpm)

V = volume of fluid, m^3, (gal.)

t = time, min.

Step 2 - Determination of Pump Capacity

Establish whether the pump will be used continuously (more than 8 hours per day) or intermittently. Determine pump capacity, Q_p, as follows:

Continuous duty $Q_p = 2 \times Q_s$ m^3/min (gpm)

Intermittent duty $Q_p = 1.3 \times Q_s$ m^3/min (gpm)

Explanation: Pump capacity, Q_p, is only for ordering purposes. All subsequent calculations will be performed using system flow rate, Q_s.

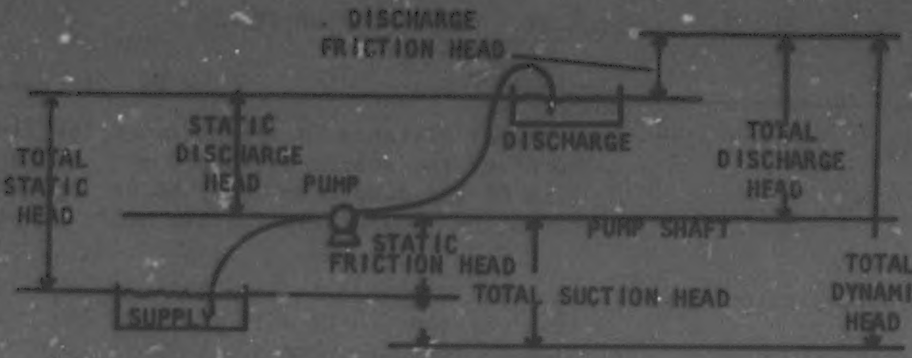
Step 3 - Sketch of Pumping System

Sketch an elevation view of the proposed pumping system (see Figure 69 and Table 29 for pertinent pumping terms). Determine whether the suction port will be flooded with fluid (Figure 69c) or whether pump location will require a static suction lift (Figure 69a). A static suction lift will require a self-priming pump. Include the following information on the sketch:

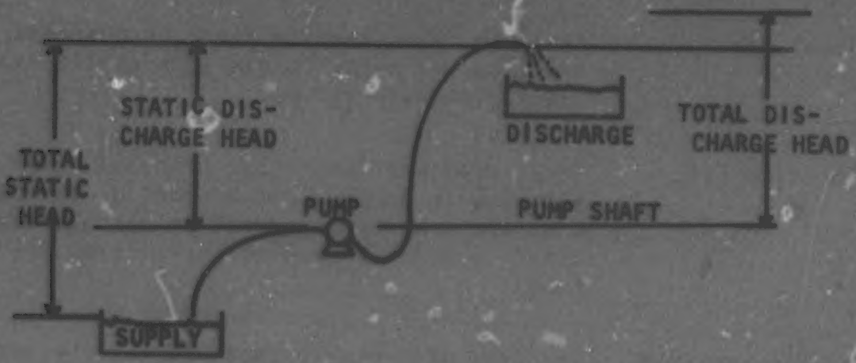
a) The vertical distance between the lowest supply fluid level and the highest discharge water level or the free discharge point. This defines the Total Static Head (TSH).

b) For self-priming applications, indicate the vertical distance between the lowest supply level fluid level and the pump centerline. This defines the Static Suction Lift (SSL).

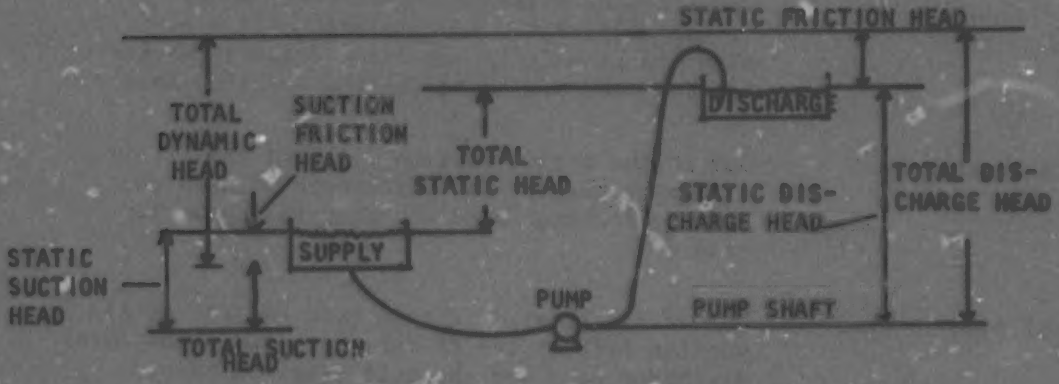
c) Indicate the approximate total length of fluid lines. Note how much is on either side of the pump.


DISCHARGE FRICTION HEAD
TOTAL STATIC HEAD
STATIC DISCHARGE HEAD
PUMP
DISCHARGE
TOTAL DISCHARGE HEAD
PUMP SHAFT
STATIC FRICTION HEAD
TOTAL SUCTION HEAD
TOTAL DYNAMIC HEAD
SUPPLY

(a) SUCTION LIFT AND SUBMERGED DISCHARGE


TOTAL STATIC HEAD
STATIC DIS-CHARGE HEAD
PUMP
DISCHARGE
TOTAL DIS-CHARGE HEAD
PUMP SHAFT
SUPPLY

(b) SUCTION LIFT AND FREE DISCHARGE


STATIC FRICTION HEAD
TOTAL DYNAMIC HEAD
SUCTION FRICTION HEAD
TOTAL STATIC HEAD
DISCHARGE
STATIC DIS-CHARGE HEAD
TOTAL DIS-CHARGE HEAD
STATIC SUCTION HEAD
SUPPLY
PUMP
PUMP SHAFT
TOTAL SUCTION HEAD

(c) STATIC SUCTION HEAD AND SUBMERGED DISCHARGE

Figure 69. Examples of typical system sketches showing pump head relationships

TABLE 29. FLUID PUMPING TERMS

Static Suction Lift	Vertical distance in feet between the liquid level of the source of supply and the centerline of the pump when the pump is located above the liquid level of the source of supply.
Static Suction Head	Vertical distance in feet between the liquid level of the source of supply and the centerline of the pump when the pump is located below the liquid level of the source of supply.
Frictional Head	Pressure (expressed in feet) to overcome friction and other losses such as fittings, transitions and valves.
Total Suction Lift	Total pressure (expressed in feet) below atmospheric at the suction port of the pump when the pump is in operation (equals the static suction lift plus the suction friction head).
Static Discharge Head	Vertical distance in feet between the centerline of the pump and the point of free delivery of the liquid.
Total Suction Head	Total pressure (expressed in feet) above atmospheric at the suction port of the pump when the pump is in operation (equals the static suction head minus the suction friction head).
Total Static Head	Sum of the static suction lift and the static discharge head or the difference between the static discharge head and the static suction head.
Total Dynamic Head	Sum of the total discharge head and the total suction lift or the difference between the total discharge head and the total suction head.
Total Discharge Head	Total pressure (expressed in feet) above atmospheric at the discharge port of the pump when the pump is in operation (equals the static discharge head and the discharge frictional head).

d) Note on the sketch the location of valves, fittings, elbows, entrances, enlargements, etc., (see Figure 70 for typical examples).

Step 4 - Preliminary Line Sizing

Using Table 30, determine a preliminary line sizing for friction head calculations.

Explanation: Pump or line size availability may later require an iteration of these calculations starting with Step 4. Ultimate pump size is affected by line size.

Step 5 - Computation of Total Dynamic Head

Use the form presented in Table 31 to compute the Total Dynamic Head.

Step 6 - Specifying Pump Rating

When ordering the pump, use the following information: Flow equal to Q_p (Step 2) at Total Dynamic Head from Step 5. Also note whether a suction lift is required and use the Total Suction Lift calculated in Step 5.

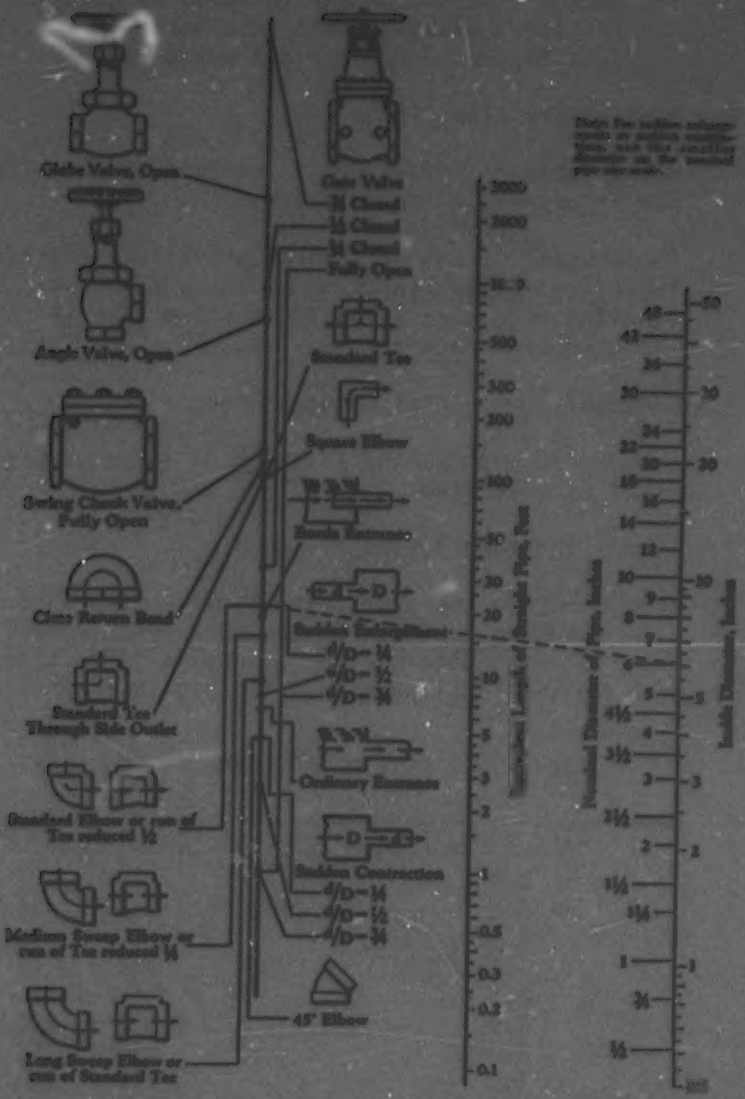
Table 30. PRELIMINARY LINE SIZING CHART

Line size, in.	Flow range, GPM
0.75	5 - 10
1.0	10 - 20
1.25	18 - 35
1.5	28 - 60
2.0	60 - 120
2.5	100 - 220
3.0	170 - 350
3.5	250 - 500
4.0	350 - 720
5.0	600 - 1300
6.0	1000 - 2000
8.0	2000 - 4200
10.0	3800 - 8000

1. Minimum represents a flow corresponding to 5 psi/100 ft friction loss, maximum corresponds to 20 psi/100 ft friction loss.

in. x 2.54 = cm

gpm x 3.785 = lpm



Use a straightedge to connect the type of restriction (left vertical line) with the nominal size (right vertical line). Read the headloss in equivalent feet on the center vertical line; e.g., a 6" standard elbow has an equivalent loss of 17 ft. (see chart) (58).

ft x .305 = m
in. x 2.54 = cm

Figure 70. Equivalent length of pipe fittings and valves

TABLE 31. FORM FOR CALCULATION OF TOTAL DYNAMIC HEAD (TDH) AND TOTAL SUCTION LIFT (TSL)

Explanation: Total Dynamic Head is needed to size the pump; Total Suction Lift is needed as part of the TDH calculation and to check the suction restriction of the pump.

A. Determine system flow rate, Q_s (from Sizing Procedure, Step 1)

________ GPM

B. Calculate Total Suction Lift or Total Suction Head (refer to Figure 69).

a. Static suction lift, or ________ Ft.
b. Static suction head ________ Ft
c. Suction friction head:

Fluid Line Head

Size (Inches)	(x) Length (Ft.)	(y) Friction Loss Per 100 Ft. (psi) From Figure 71)	$\frac{(x)\cdot(y)}{40}$ Total Line Loss (Ft.)
			________
		Total	________ Ft.

---

continued

TABLE 31 (continued)

Fitting Head

Fitting Type	Size (Inches)	(v) No.	(w) Equivalent Length Per Fitting (From Figure 70) (Ft.)	$\frac{(v)\cdot(w)\cdot(y)}{40}$ Total Equivalent Length (Ft.)

Total ______ Ft.

c. Suction friction head = fluid line head ______ Ft.
+ fitting head ____ Ft. = ____ Ft.

d. Total suction lift = $\frac{(a) + (c)}{\text{Specific Gravity}}$ = ______ Ft.

Explanation: If total suction lift is higher than 15 feet, reduce it by:

1) Lowering the pump
2) Increasing the size of the suction line and/or decreasing the overall length of line
3) Eliminating unnecessary fittings
4) Decreasing the flow

15 ft is the desired maximum condition

e. Total suction head = $\frac{(b) - (c)}{\text{S.G.}}$ = ______ Ft.

S.G. = Specific Gravity

continued

TABLE 31 (continued)

C. Calculate Total Discharge Head (refer to Figure 69)

f. Static discharge head ________ Ft.

g. Discharge friction head:

Fluid Line Head

Size (inches)	(x) Length (Ft.)	(y) Friction Loss Per 100 Ft. (psi) (From Figure 71)	$\frac{(x)\cdot(y)}{40}$ Total Line Loss (Ft.)

Total ________ Ft.

Fitting Head

Fitting Type	Size (inches)	(v) No.	(w) Equivalent Length Per Fitting (From Figure 70) (Ft.)	$\frac{(v)\cdot(w)\cdot(y)}{40}$ Total Equivalent Length (Ft.)

Total ________ Ft.

continued

TABLE 31 (continued)

Discharge friction head = fluid line head ________ Ft.

+ fitting head _____ Ft. = ______ Ft.

h. Total discharge head = $\frac{(f) + (g)}{S.G.}$ = ________ Ft.

S.G. = Specific Gravity

i. Total dynamic head (TDH) = Total discharge head + total suction lift or total discharge head - total suction head

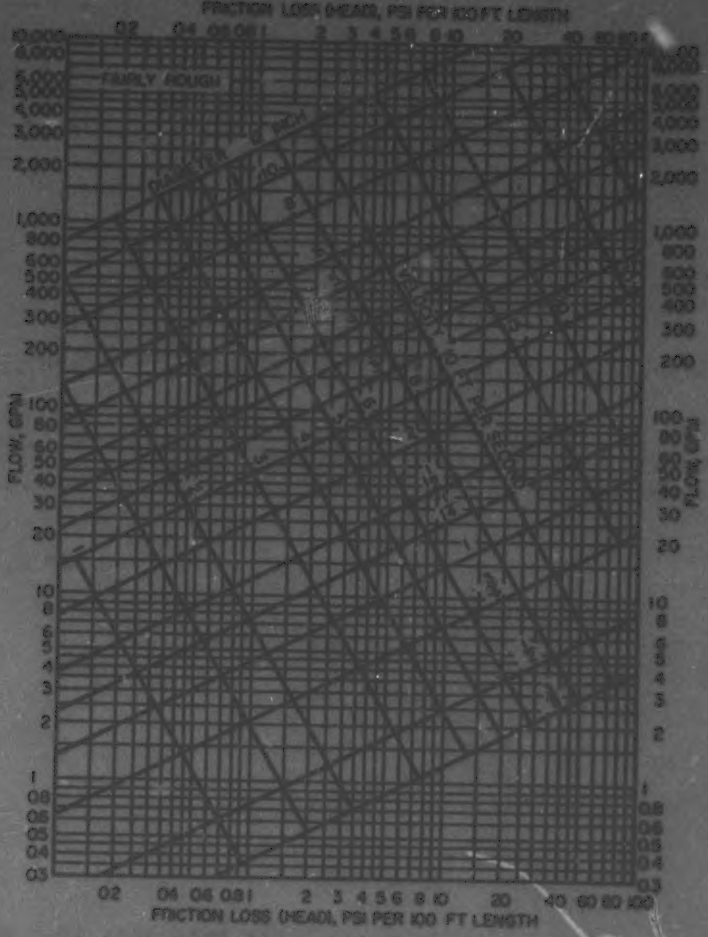
TDH = (h) + (d) ________ Ft.

or

TDH = (h) - (e) = ________ Ft.

---

ft x .305 = meters



METRIC CONVERSION

ft x .305 = meters
gal. x 3.785 = liters
psi x .0703 = kg/cm^3

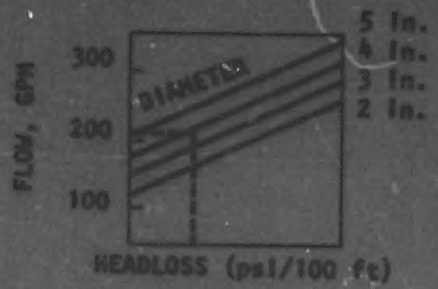
(REFER TO FIGURE 72 FOR USE OF GRAPH)

Figure 71. Friction loss in water piping (58).

1. Determine the head loss (psi/100 ft.) associated with a flow of 200 GPM through a 4" pipe.

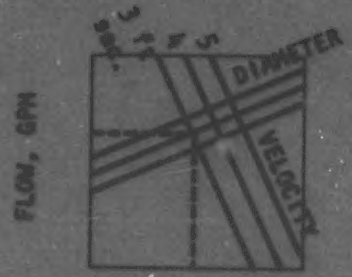
Conversions

gpm x 3.785 = lpm
ft x .305 = m
psi x 703.1 = kg/m^2
in. x 2.54 = cm



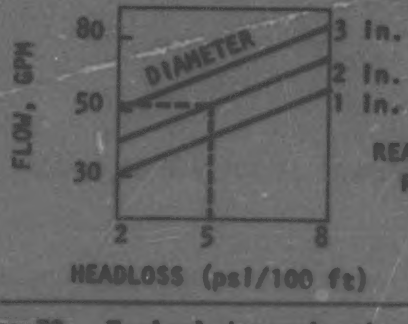
READ HEADLOSS AS 1.5 psi/100 ft EQUIVALENT LENGTH

2. Determine the flow rate (GPM) to produce a minimum flow velocity of 3 ft./sec in a 4 inch line.



READ FLOW AS 120 GPM

3. Determine the line size (inch) to limit head loss to 5 psi/100 ft. at a flow of 50 GPM.



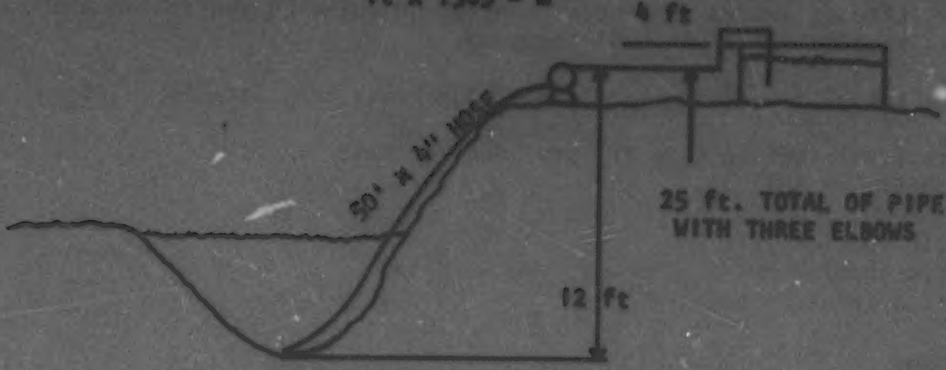
READ LINE SIZE AS 1.8" --
ROUND UP TO 2"

Figure 72. Typical determinations made from the Friction Loss Chart (Figure 71)

Example:

Note: All calculations are in English units; the following conversions are appropriate:

gal. x 3.785 = liters
in. x 2.54 = cm
ft x .305 = m



Size a pump to empty a ditch with an estimated capacity of 100,000 gallons in 8 hours. The fluid is water with a dilute contaminant and a low solids content. The liquid will be pumped into a 10,000 gallon swimming pool which will act as a pretreatment tank. Another pump of equal or creater capacity will then pump to subsequent treatment processes. A 4 inch diameter x 50 feet suction hose is available to reach the low point in the ditch from a suitable location for installing the pump. Sufficient pipe of various sizes is available on site to make the pump discharge connection into the pool. Refer to Table 31a for compilation of the results.

Step 1 - Calculation of System Flow Rate

$$Q_s = \frac{V}{t} = \frac{100,000 \text{ gal.}}{8 \text{ hours}} \times \frac{1 \text{ hour}}{60 \text{ min.}} = 208 \text{ GPM}$$

Step 2 - Determination of Pump Capacity

$$Q_p = 2 \times Q_s = 416 \text{ GPM} \quad \text{(Continuous duty)}$$

Step 3 - Sketch of Pumping System

The presence of a suction lift will require a self-priming pump. The highest discharge point is the top of the tank, 4 ft. above the pump centerline. The lowest suction point is 12 ft. below the pump centerline. The Total Static Head is 16 ft.

TABLE 31a. COMPLETED FORM FOR CALCULATION OF TOTAL DYNAMIC HEAD (TDH) AND TOTAL SUCTION LIFT (TLS)

Explanation: Total Dynamic Head is needed to size the pump; Total Suction Life is needed as part of the TDH calculation and to check the suction restriction of the pump.

A. Determine system flow rate, Q_s (from Sizing Procedure, Step 1) 208 gpm

B. Calculate Total Suction Life or Total Suction Head (refer to Figure 69).

a. Static suction lift ____ ft
b. Static suction head ____ ft
c. Suction friction head ____ ft

Fluid Line Head

Size, in.	(x) Length, ft	(y) Friction loss per 100 ft, psi (from Figure 71)	$\frac{(x)\cdot(y)}{40}$ Total line loss, ft
4	50	1.9	2.4

TOTAL 2.4 ft

Fitting Head

Fitting type	Size, in.	(v) No.	(w) Equivalent length per fitting, ft (from Figure 70)	$\frac{(v)\cdot(w)\cdot(y)}{40}$ Total Equivalent length, ft
ordinary entrance	4	1	6	0.3

TOTAL 0.3 ft

Suction friction head = fluid line head (2.4 ft) + fitting head (0.3) ft

= 2.7 ft

continued

TABLE 31a (continued)

d. Total suction life = $\frac{(a) + (c)}{\text{specific gravity}}$ = 14.7 ft.

Explanation: If total suction lift is higher than 15 ft, reduce it by:

1) Lowering the pump
2) Increasing the size of the suction life and/or decreasing the overall length of line
3) Eliminating unnecessary fittings
4) Decreasing the flow

15 feet is the desired maximum condition

e. Total suction head = $\frac{(b) - (c)}{\text{specific gravity}}$ = ____ ft.

C. Calculate Total Discharge Head (refer to Figure 69)

f. Static discharge head 4 ft
g. Discharge friction head:

Fluid Line Head

Size, in.	Length, ft	(y) Friction loss per 100 ft, psi (from Figure 71)	$\frac{(x)\cdot(y)}{40}$ Total line loss, ft.
3	25	8	5
		TOTAL	5 ft

Fitting Head

Fitting type	Size, in.	(v) No.	(w) Equivalent length per fitting, ft (from Figure 70)	$\frac{(v)\cdot(w)\cdot(y)}{40}$ Total Equivalent length, ft
elbow	3	3	8	4.8
sudden enlargement	3	1	1.8	0.4
			TOTAL	5.2 ft

continued

TABLE 31a (continued)

Discharge friction head = fluid line head (5 ft) + fitting head (5.2 ft)

= 10.2 ft

h. Total discharge head = $\frac{(f) + (g)}{\text{specific gravity}}$ = 14.2 ft

i. Total dynamic head (TDH) = total discharge head + total suction lift

or total discharge head - total sunction head

TDH = (h) + (d) 28.9 ft

or

TDH = (h) - (e) = ______ ft

---

ft x .305 = meters

Step 4 - Preliminary Line Sizing

From Table 30 choose a pipe which will be suitable on the discharge for the preliminary calculation. A check of the available pipe on site indicates that, of the two sizes, only 3" is available.

Step 5 - Computation of Total Dynamic Head

From form in Table 31a TDH = 28.9 ft.

Step 6 - Specifying Pump Rating

416 GPM at 28.9 ft TDH
Self-priming pump required

7.2.3 Selection of Available Pumps

The best local sources for suitable pumps to implement field treatment processes are probably contractors' supply houses and contractors themselves. They can supply pumps as well as limited lengths of hose. Secondary local sources are the local sewage treatment plant, the department of public works, and fire departments. Table 32 presents a selection chart based on pump usage variables and available pump types. The type designations used (A-D) will be found in other sections of this manual when referring to these pump types. The following are descriptions and typical ratings of these available pumps:

Type A - Medium pressure centrifugals

The most available variety is the self-priming, engine driven centrifugal pump. This type of pump is used by contractors in a variety of sizes and ratings as shown in Table 33.

TABLE 33. TYPICAL RATING FOR MEDIUM PRESSURE CENTRIFUGAL PUMPS

	Portable	Wheel mounted	Skid mounted	Tractor PTO
Size range (inches)	1½ - 3	1½ - 8	10	3-8
Flow range (gpm)	25-350	20-2500	250-3750	50-2000
Total head range (ft)	20-140	0-220	30-120	23-438
Horsepower range	3-7	3-150	100-150	

ft x 3.05 = m
in x 2.54 = cm
fpm x 3.785 = lpm
hp x .746 = kw

TABLE 32. PUMP SELECTION CHART

	Medium Pressure Centrifugal	High Pressure Centrifugal	Heavy Duty Trash	Diaphragm
Pump Type Designation	A	B	C	D
1. Fluid Transfer -				
med. pressure	x		x	x
high pressure		x		
Solids handling			x	x
2. Suction Condition				
Flooded suction	x	x	x	x
Suction lift	x		x	x
Submersible pump	x			
3. Power Source				
Engine driven	x	x	x	x
Air driven				x
Electrical	x	x	x	x
Power takeoff	x		x	
4. Mobility				
Portable (by one to three men)	x		x	
Wheel mounted	x	x	x	x
Skid mounted	x	x	x	x
Tank truck mounted			x	

Although the pump is self-priming, an initial prime is required. A pipe plug on top of the pump body must be removed and the pumping chamber filled with water. Even though it may run dry for a short period, the pump should still hold its prime by virtue of the priming chamber design. The pump can handle solids, but it is not a good choice as a solids pump because of inaccessibility to remove fouling.

Another available centrifugal pump which finds extensive application in dewatering is the electric submersible pump.

Typical ratings:

	English units	Metric units
Size range	2-8 inches	5-20 cm
Flow range	50-2800 gpm	0.2-10.6 cu m/min
Total head range	10-200 ft	3-61 m
Power	2-95 hp	1.5-71 kw

Type B - High Pressure Centrifugals

These engine-driven pumps are commonly used for high pressure testing of plumbing systems. While not self-priming, they are generally furnished with an exhaust or vacuum primer.

Typical ratings:

Size range	2.5-6 inches	6.3-15 cm
Flow range	50-1800 gpm	0.2-6.8 cu m/min
Total head range	70-460 ft	21-140 m
Power	5-125 hp	3.7-93 kw

Type C - Heavy Duty Trash Pumps

A readily available variety of solids handling pumps is the engine-driven, self-priming, centrifugal, trash pump which has the same variety of sizes, mountings, and ratings as the Type A - Medium Pressure, Engine Driven Centrifugals. There are two major differences between the medium pressure and the trash handling centrifugals:

The pump body and impeller of the trash pump are open to allow the passage of large solids; solids ratings are given as the maximum diameter of a spherical solid which the pump could pass:

Pump size		Largest sphere passed*	
cm	In.	cm	In.
3.8	1.5	2.5	1
5	2	2.8-3.8	1.1-1.5
7.6	3	3.8-6.3	1.5-2.5
10.1	4	5-7.6	2-3
15.2	6	6.3-7.6	2.5-3

* Termed solids handling ability

The self-priming trash pump is used on sanitary cleaning trucks, used by septic tank cleaners and other waste fluid haulers. It is typically available in 10.1 cm (4") size on a tank truck of 4.1, 6.0 or 8.3 cu m (1100, 1600, 2200 gal.).

Another type designed for solids-laden streams is the electrical or engine-driven diaphragm pump. This recirprocating pump utilizes a flexible, elastomeric diaphragm which is flexed and extended by a mechanical eccentric drive. Check valves are necessary to permit the pulsing pump action. It is preferred to utilize hardwall hose on both suction and discharge to minimize the surging forces on the hoses, hose supports, and tanks. This pump is normally available in the portable and small wheel-mounted varieties with typical ratings as follows:

	English units	Metric units
Size range	3-4 inches	7.6 cm
Flow range	50-150 gpm	189-568 lpm
Total dynamic head range	5-50 ft	1.5-15 m
Power	0.5-7 hp	0.4-5 kw

Type D - Mechanical and Pneumatic Diaphragm Pumps

This solids-handling pump usually comes in single diaphragm engine-driven, portable varieties with the pumping action occurring because of the reciprocal movement of a diaphragm driven by an eccentric. Swing check valves on inlet and outlet permit fluid pumping. The pulsing nature of the pumping can cause severe hose whipping if hoses are not properly supported. Typical ratings are as follows:

Size range	3-4 inches	7.6-10.2 cm
Flow range	52-150 gpm	197-5680 lpm
Total head range	5-50 ft	1.5-15 m
Power	2.75-6.6 hp	2.0-4.9 kw

Diaphragm pumps function best with a short suction line and low suction lift.

Air Operated Double Diaphragm Pumps

The air-operated diaphragm pump is an excellent pump for solids handling at higher head ratings than the typical mechanical diaphragm pump. It is light weight, portable and self-priming, and may also be utilized as a submersible pump. A single air pressure line is all that is required for hookup, except in the case of the submersible pump, where a vent line must extend above the water surface so that the air suction of the pump does not fill with water when the pump is shut off. The The pump has a reciprocal motion with pumping occurring by the movement of the diaphragm controlled by an air valve and the opening and closing of ball check valves on the inlet and outlet. It has a smoother motion in many cases than mechanical diaphragm pumps. However, hose whipping must be controlled when using this pump also. The pump would be more resistant to explosion or fire hazards than engine-driven or electric motor-driven pumps. It could, however, freeze up in cold weather because of the expansion of air in the air valve. The pumping rate can be easily controlled by controlling air flow to the pump. Typical pump specifications are in the following table. (Table 34)

TABLE 34. TYPICAL AIR PUMP SPECIFICATIONS

Air requirements		Pumping capacity			
		2" size		3" size	
Pressure, psig	Air consumption, scfm	Flow, gpm	Head, ft	Flow, gpm	Head, ft
100	160			170	85
	140			138	125
	120			110	155
	100			83	183
	80	110	55	40	202
	60	58	170	41	218
	40	28	205	25	222
	20	12	220	20	226

psig x 703 = kg/sq m
scfm x .028 = s cu m/min
gpm x 3.785 = lpm
ft x .305 = m

Pumps can also be operated at lower pressures with varying pumping capacities. Maximum solids size ratings are .63 cm (1/4") diameter for a 5 cm (2") pump and 0.95 cm (3/8") for a 7.6 cm (3") pump.

7.2.4 Special and Hazardous Pumping Situations

Special problems occur when handling viscous fluids, high solids content, and flammable and explosive substances. Special care must be taken when applying pumps for these situations because of the danger of failure or of hazards to personnel.

7.2.4.1 Viscous fluids - Increased viscosity above that of water causes a need for a higher pumping head than is needed to pump water at the same flow rate. The viscosity of all fluids varies appreciably with changes in temperature. The viscosity of some fluids is unaffected by the mechanical motions occurring during transport (Newtonian fluids such as mineral oil and water). A liquid is said to be thixotropic if viscosity decreases as agitation is increased (asphalt, molasses). A liquid is said to be dilitant if viscosity increases as agitation occurs (clay slurries).

Because of the above complexities as well as the difficulty in getting viscosity measurement in the field, it is not easy to establish a calculation method to be used for field sizing of pumping systems for handling viscous fluids. In the absence of a sizing technique, it is desirable to choose a pump for viscous pumping service which has a head capacity substantially higher than that which is necessary to pump water at the same rate. Ultimate flow rate must be established in actual service. It is desirable when pumping viscous fluids to reduce the number of restrictions and to keep line velocities low and suction line length to a minimum.

7.2.4.2 Solids Handling - Again, calculation methods are not available for solids pump sizing because of a number of factors such as: solids concentration; viscosity; specific gravity; particle size; presence of various constitutents such as silt, clay, sand, debris. Like the viscous flow situation, an elevated head is needed to pump high solids concentrations, but in addition a minimum transport velocity is necessary to insure against solids settling in the lines. This minimum velocity is in the range of 0.61 - 0.92 m/sec (2-3 ft/sec) and is a function of line size and solids concentration.

If the cleanup operation will involve a major amount of dredging it would be desirable to enlist the services of a dredging firm to advise on the best pumping system configuration. Such items as suction line backflush capabilities and pump and hose cleanout must be considered to reduce downtime from clogged lines, pumps, and valves.

7.2.4.3 Flammable and Explosive Substances - Serious hazards can be created by pumping systems when handling explosive or flammable fluids:

1. Ignition sources such as spark plugs, ignition wire and switches, hot mufflers and engine blocks, combustile air filters, open electric motors, static electricity buildup, are ever present dangers when using readily available contractor's pumping equipment.

2) Pump suctions, and restrictions can cause gases to be created in excess of the lower explosive limit because of regions of reduced pressure.

Because of the imminent dangers of field implemented treatment systems when dealing with dangerous substances, it is recommended that the manufacturer of flammable or explosive substances be contacted concerning safe ways to handle these products. In some cases the dangers may preclude field treatment unless the substance can be rendered less hazardous.

7.3 PROCESS TANKS

The availability of process tanks is critical to the determination of feasible system flow rates because of the detention times required by the various process schemes. Unlike portable pumps, which are readily available because of extensive requirements by contractors to dewater construction sites, a limited variety of tanks are available which could be turned to field treatment process uses. Some available tanks include:

Open Top Tanks:

1. Commercially available above-ground swimming pools;
2. U.S. Army Corps of Engineers rubber stave tanks;
3. Impermeable membranes as liners for earthen excavations or for steel, concrete, or wooden tanks;
4. Treatment of earthen excavations with high-swelling clay to make the soil impermeable;
5. Culvert, storm, drain, and sewer pipe utilized for vertical column tanks;
6. Specialized steel, fiberglass, and lined wooden tanks borrowed from local industries.

Closed Tanks:

1. ASME tanks with flanged and dished heads;
2. Tank trucks;
3. Collapsible rubber containers.

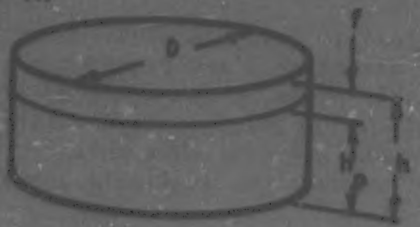
By far, the most practical tank for field implemented treatment processes is the open top tank, which has the necessary accessibility for operation and control of the process. For most processes, geometry is not a critical parameter, with the notable exceptions of filtration, carbon adsorption, and ion exchange. In gravity feed systems these processes require vertical tanks of uniform cross-section and height-diameter ratios typically greater than two. Closed tanks are mainly limited to storage and transfer functions, such as clean effluent storage for backwash or sludge storage and disposal. In an emergency, process operations can be carried out in closed tanks, however, the operation is tedious.

Tank sizing will require that the process volume for the various tanks be known. The following section (Section 7.3.1) gives formulae for calculation of process volumes for a variety of tank configurations. Then, Section 7.3.2 presents a description of various available tanks as well as some pertinent details concerning their installation and use.

7.3.1 Calculation of Process Volume

Typical above ground and in-ground tanks have been classified in Figure 73 as specific tank designations (A-H). These type designations are used in other portions of the manual when referring to specific tank types.

TYPE A.

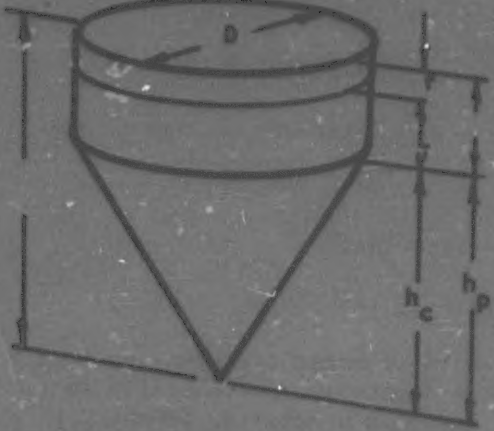


VERTICAL CYLINDER, FLAT BOTTOM, OPEN TOP

D = DIAMETER, m (ft)
h = TANK HEIGHT, m (ft)
h_p = PROCESS HEIGHT, m (ft)
f = FREEBOARD, m (ft)

PROCESS VOLUME $V_p = \frac{\pi D^2}{4} \times h_p = 0.78D^2 \times h_p$ m^3, (ft^3)

TYPE B.

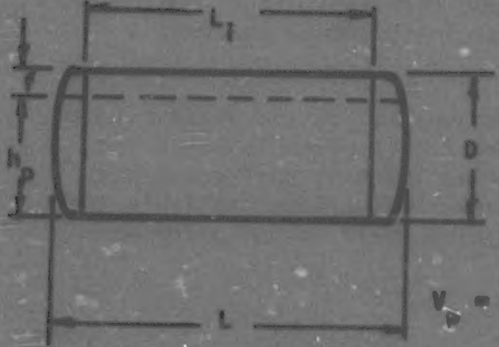


VERTICAL CYLINDER, CONE BOTTOM, OPEN TOP

D = DIAMETER OF CYLINDRICAL SECTION, m (ft)
h = TANK HEIGHT, m (ft)
h_p = PROCESS HEIGHT, m (ft)
f = FREEBOARD, m (ft)
L = HEIGHT OF STRAIGHT SECTION, LESS FREEBOARD, m (ft)
h_c = CONE HEIGHT, m (ft)

PROCESS VOLUME $V_p = D\ (.78L + .26\, h_c)$ m^3, (ft^3)

TYPE C.



ASME TANK, HORIZONTAL

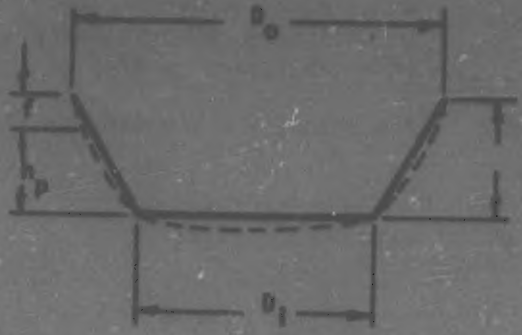
D = DIAMETER, m (ft)
h_p = PROCESS HEIGHT, m (ft)
f = FREEBOARD, m (ft)
L_I = LENGYH OF STRAIGHT SIDE, m (ft)
L = TOTAL LENGTH, m (ft)
V_H = VOLUME OF HEAD (See Figure 74)

$V_p = .78D^2 L_I + 2V_H$ m^3, (ft^3)

1. THIS VOLUME IS TANK CAPACITY WITHOUT SUBTRACTION FOR FREEBOARD

Figure 73. Calculation information for tank volumes.

TYPE D.

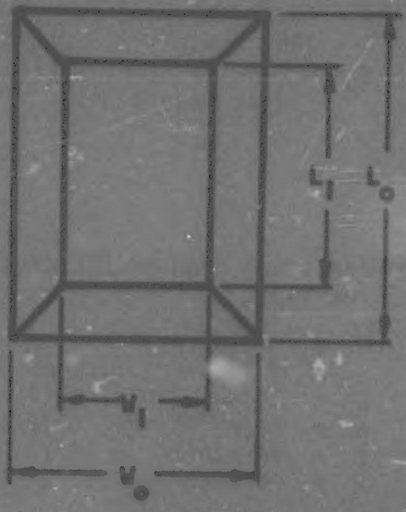


CYLINDRICAL IN-GROUND TANK (APPROXIMATION OF FRUSTRUM OF RIGHT CIRCULAR CONE)

D_o = OUTSIDE DIAMETER, m (ft)
D_i = INSIDE DIAMETER, m (ft)
h = TANK HEIGHT, m (ft)
h_p = PROCESS HEIGHT, m (ft)
f = FREEBOARD, m (ft)

$$V_p = .52\ D_o^2\ \left[1 + \frac{D_i}{D_o} + \frac{(D_i)^2}{(D_o)}\right] \times h_p \quad m^3, (ft)$$

TYPE E.



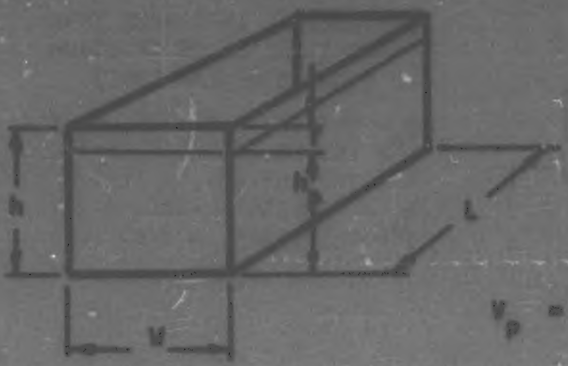
RECTANGULAR IN-GROUND TANK (APPROXIMATION OF OBELISK) (ELEVATION VIEW SIMILAR TO D ABOVE)

L_o = OUTSIDE LENGTH, m (ft)
L_i = INSIDE LENGTH, m (ft)
W_o = OUTSIDE LENGTH, m (ft)
W_i = INSIDE LENGTH, m (ft)
h = TANK HEIGHT, m (ft)
h_p = PROCESS HEIGHT, m (ft)
f = FREEBOARD, m (ft)

$$V_p = \frac{1}{6}\ [W_oL_o + (W_o + W_i)\ (L_o + L_i) + W_iL_i] \times h_p \quad m^3, (ft)$$

Figure 73 (continued). Calculation information for tank volumes.

TYPE F.

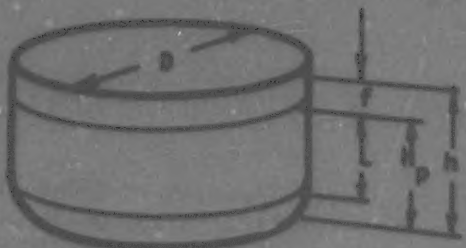


W = WIDTH, m (ft)
L = LENGTH, m (ft)
h = TANK HEIGHT, m (ft)
h_p = PROCESS HEIGHT, m (ft)
f = FREEBOARD, m (ft)

FOR SQUARE W = L = SIDE, m (ft)

$V_p = WLh_p$ m^3, (ft^3)

TYPE G.

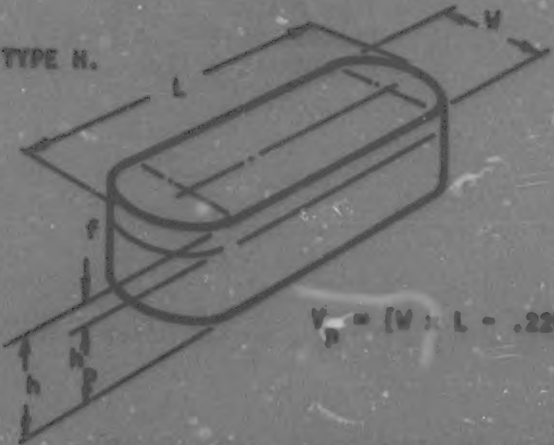


VERTICAL CYLINDER, ASME FLANGED AND DISHED HEAD ON BOTTOM

D = DIAMETER, m (ft)
L = LENGTH OF STRAIGHT SECTION LESS FREEBOARD, m (ft)
h_p = PROCESS HEIGHT, m (ft)
f = FREEBOARD, m (ft)
h = TANK HEIGHT
V_H = VOLUME OF HEAD, m^3 (ft^3) (See Figure 74)

$V_p = .78D^2L + V_H$ m^3, (ft^3)

TYPE H.



VERTICAL, OVAL-SHAPED CYLINDRICAL TANK

W = WIDTH, m (ft) (diameter of round end)
L = TOTAL LENGTH, m (ft)
h = TOTAL HEIGHT, m (ft)
f = FREEBOARD, m (ft)
h_p = PROCESS HEIGHT, m (ft)

$V_p = [W \times L - .22W^2] \times h_p$ m^3, (ft^3)

Figure 73 (continued). Calculation information for tank volumes.

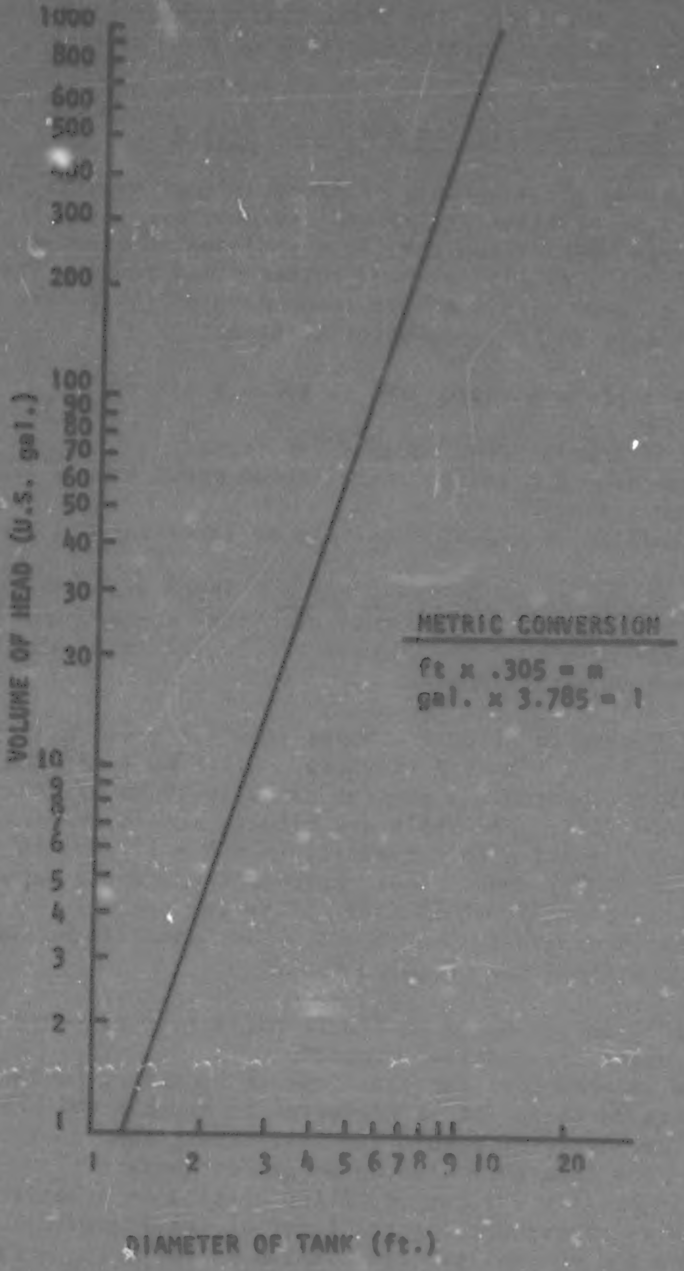


Figure 74. ASTM head volumes

The calculation for process volume allows for freeboard, which is a process requirement. Determination of freeboard must also take into account the hazard associated with the fluid, the structural stability of the tank, imminent dangers of leaking or overpressurization and the controllability of the process against overflowing.

7.3.2 Available Tanks - Description and Installation

The following tanks may fit a variety of process requirements. They were chosen on the basis of availability as well as desirability. It will be noted that some tanks most suited for field implemented treatment schemes are probably not locally available, e.g. rubber stave tanks. They are included however, to emphasize the need to make suitable process equipment available to facilitate field-implemented treatment.

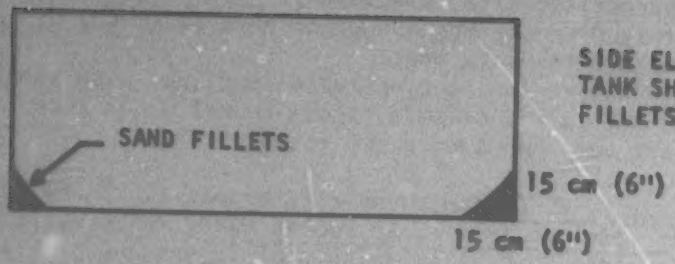
Installation details are presented here to allow the user to:

1. Be aware of special requirements for tanks.
2. Allow tank choice based on installation requirements and site considerations.
3. Become familiar with actual methods of installation.

7.3.2.1 Type A - Above Ground Swimming Pools - There are many types of commercially available pools but the most practical variety utilizes a flexible liner (usually 0.5 mm (or 20 mil) vinyl), finished steel sheet sides, and aluminum pedestal supports.

The pools typically come in circular shapes from 4.6 - 8.5 m (15-28 ft) in diameter and from 1.2 - 2.1 m (4-7 ft) deep. Allowing a minimum of 15 cm (6") freeboard, this represents a process capacity range of from 17.5 - 113.2 cu m (620-4000 ft^3). The pools are also typically available in oval shapes from 3.7 x 7.3 m (12 x 24') overall, to 4.9 x 12.2 m (16 x 40') overall, at 1.2 - 2.1 m (4-7') deep. This represents a process capacity range of from 25.5 - 107.6 cu m (900-3800 ft^3). They can probably be set up on a prepared site by three men in four hours. Four specific precautions are necessary in the field use of these tanks:

1. They should be set up on as flat a surface as possible with a solid base under the pedestal supports.
2. A smooth undersupport for the liner is necessary, with all sharp objects removed. It is preferred to support the liner above 5-10 cm (2-4") of sand or to install a ground cloth below the liner for insurance when on an uneven surface.
3. A 15 x 15 cm (6 x 6") curved fillet of sand is necessary to provide a radius of support for the liner at the juncture between the bottom and the walls. (See sketch on following page.)
4. Whenever a process component is introduced into the tank, e.g. hose thrown over the side, submersible pump installed on the bottom, etc., a piece of rubber or thick plastic should be installed to protect the liner from puncture.



SIDE ELEVATION VIEW OF
TANK SHOWING RADIUS
FILLETS OF SAND

Installation steps can be summarized as follows:

1. Choose a flat and open surface for installation.
2. Remove protruding objects, and place 5-10 cm (2-4 in.) of sand or a heavy ground cloth over chosen area to prevent rupture.
3. Build sand fillets around the radius of the pool.
4. Install pool (see Instruction Manual provided with pool).
5. Place protective liner inside the pool for added safety.

7.3.2.2 Type A - U.S. Army Corps of Engineers Portable Tanks - There is an open top tank with far better field implementation possibilities than the swimming pool, but with limited availability. This is the Army Corps of Engineers Collapsible Water Tank. This tank comes in two sizes: 5.7 and 11.4 cu m (1500 and 3000 gal.) A modified version of this tank in the 568 cu m (15,000 gal.) size has been used very successfully in the hazardous spills trailer treatment system. Tank construction is neoprene coated nylon material which is a tough, corrosion resistant material. The tank can be set up almost anywhere, is not easily susceptible to puncture, and has tank fittings to accommodate process hookups. Instead of the aluminum sidewall pedestals used by the swimming pool for support of the liner, the stave tank uses wooden slats which are quickly installed through stave pockets in the tank walls.

On soft or wet ground, boards would be placed under each stave to prevent sinking of the staves, which could result in their bowing out and cracking. Ground surface preparation involves removal of protruding objects which could puncture the liner. Spreading of 5-10 cm (2-4 inches) of sand under the tank can provide insurance against such punctures as well as use of the rubber ground cloth which comes with the tank.

Support bars span the top of the tank to maintain a circular cross section and guy ropes provide restraint against tipping. They can be fastened with stakes or just tied to water-filled or sand-filled barrels. The tank comes with a repair kit should a material failure occur. After disassembly, the tank, staves, and poles can be stored in a relatively small container.

Installation can be summarized as follows:

1. Choose appropriate site (flat/open)
2. Remove protruding objects and place 5-10 cm (2-4") of sand under tank to provide safe base.
3. Install tank (see instruction manual provided with tank).
4. If the ground is wet or soft, place boards under each stave.
5. Add support bars and secure guy ropes.

7.3.2.3 Types A, D, E, F, G Impermeable membranes as liners for earthen excavations or for steel, concrete, or wooden tanks - Synthetic flexible membranes have been long used as swimming pool liners and tank liners for water softeners but more recently are being used extensively in lining of ponds and canals, and in many other types of earthen excavations. New materials are being introduced regularly but at the present time, PVC, polyethylene, EPDM rubber, Hypalon, and chlorinated polyethylene, either with or without reinforcements are finding applications. The liners are available in large sheets with the exception of pool liners (20 gauge vinyl) which may be specially constructed to fit a certain size excavation. Where sheets are used in small excavations, a number of ruffled folds are necessary to make the flat sheet fit the contour, but this is not detrimental to process treatment. In large excavations, overlapping and sealing of the sheets is necessary. The differences between the available materials are summarized in Table 35.

Many of the polymers are produced with fabric reinforcements, varying from light-weight nylon scrims to very heavy nylon or polyester scrims, producing a variety of material strengths.

The earth itself has to be loadbearing in order to support the weight of the water and the membrane's function is to make the ground impermeable. It is necessary to remove all debris which might cause damage, including stones, roots, etc. A sand layer base of 5-10 cm (2-4") is desirable. When forming the sand on inclined surfaces the sand should be wetted and troweled if possible.

When liner sections are overlapped, the water pressure tends to stabilize the joint by compression, minimizing seepage through improper joints.

The following summarizes the installation procedures:

1. Choose or excavate appropriate area.
2. Remove debris.
3. Place a sand layer 5-10 cm (2-4") thick if possible - wet and trowel sand on inclined surfaces.
4. Place and seal liner in place (see instructions accompanying liner).

7.3.2.4 Types D and E - Excavations treated with highly colloidal clay - This method of converting an excavation into a sealed tank involves treating the upper layer of soil with a clay which, when wetted, swells many times its volume and forms an impermeable seal. The material, called volclay, or bentonite, consists chiefly of hydrous aluminum silicate and is mined

TABLE 35. SYNTHETIC LINER MATERIALS

Material	Thickness	Guage	Length	Width	Sealing Method	Comments
Polyethylene	2-8 mils	light	any	up to 40'	heat or adhesion	1. least expensive 2. fairly stiff and may not conform to irregularities 3. heat seal is best but difficult to do in the field.
Polyvinyl Chloride	8-40 mil	heavier	up to 700 ft.	up to 70 - 80 ft.	solvent made	1. much stronger and tougher than all 2. Good bonding 3. Expensive
Butyl and EPDM Rubber	32-125 mil	medium	any	20 ft.	heat	1. Difficult to seal since it is a vulcanized product 2. Moderate toughness and puncture resistance 3. highly extensible
Hypalon and Chlorinated Polyethylene	30 mil	medium	any	4-20'	solvent	1. intermediate strength elongation and toughness 2. easily available in large panels
Vinyl	8-35mil	light	any	4-61 ft.	heat, solvent or adhesive	1. normal swimming pool liners 2. excellent puncture resistence

almost solely in the Black Hills region of the U.S. Information on the availability of product may be obtained from:

American Colloid Co.
5100 Suffield Court
Skokie, Illinois 60076

The material may be loaded onto a bulk lime fertilizer spreader to apply a uniform cover of the material over the tank area. Using a farm disk, Volclay is mixed into the top 5-7.6 cm (2-3") of soil. The Volclay-soil mixture is returned to its approximate original density with a wobble-wheel or steel wheel roller before being wetted. For small tanks, the above operations could all be performed by hand. Caution. Care must be taken, however, to wear respirators to prevent excessive inhalation of the submicron clay dust.

7.3.3 Column Tank Options

Type A column tanks for filters, carbon columns, and ion exchange columns:

A. Tanks constructed of corrogated steel pipe.

This piping is generally available in 20 foot lengths in the diameters and gauges shown in Table 36. Where fittings are to be installed on the tank or other welding is to be done, 14 gauge or lower is preferred. Pipes can be cut to desired tank height.

B. Tanks constructed of reinforced concrete culvert, storm, drain, and sewer pipe (see Table 37).

Caution: Be sure to use reinforced concrete to avoid excessive strain in the column.

When O-ring gaskets are used, it may be desirable to stabilize the tank by nailing several 2x4 wood straps across the joint at spaced intervals around the periphery.

C. Foundations for Column Tanks

A base of reinforced concrete must be poured for each column tank. These foundations are to be placed on firm soil. Field tests to determine firm soil on the basis of soil strength and density are shown in Table 38.

TABLE 36. INFORMATION ON CORROGATED STEEL PIPE (59)

Corrugation & Diam.			** Gages and Thicknesses Available in Inches					
2 2/3" x 1/2" & 2" x 1/2"	3" x 1"	End Area Sq. Ft.	18 .052	16 .064	14 .079	12 .109	10 .138	8 .168
12 in.		.79	*	*	*			
15		1.23	*	*	*			
18		1.77	*	*	*	*		
21		2.40	*	*	*	*		
24		3.14	*	*	*	*		
27		3.98		*	*	*		
30		4.91		*	*	*		
33		5.94		*	*	*		
36		7.1		*	*	*	*	
	36 in.		*	*	*	*	*	*
42		9.6		*	*	*	*	*
	42		*	*	*	*	*	*
48		12.6		*	*	*	*	*
	48		*	*	*	*	*	*
54		16.0			*	*	*	*
	54		*	*	*	*	*	*
60		19.6			*	*	*	*
	60		*	*	*	*	*	*
66		23.8			*	*	*	*
	66		*	*	*	*	*	*
72		28.3				*	*	*
	72		*	*	*	*	*	*
78		33.2				*	*	*
	78		*	*	*	*	*	*
84		38.5					*	*
	84		*	*	*	*	*	*
90		44.2					*	*
	90		*	*	*	*	*	*
96		50.3					*	*
	96			*	*	*	*	*
	102	56.7		*	*	*	*	*
	108	63.6			*	*	*	*
	114	70.9			*	*	*	*
	120	78.5				*	*	*

in. x 2.54 = cm
sq ft x 0.093 = sq m

TABLE 37. REINFORCED CONCRETE PIPE INFORMATION

WALL A			WALL B		WALL C	
Internal Diameter, inches	Minimum Wall Thickness, inches	Average Weight, pounds per foot	Minimum Wall Thickness, inches	Average Weight, pounds per foot	Minimum Wall Thickness, inches	Average Weight, pounds per foot
12	1 3/4	79	2	93	-	-
15	1 7/8	103	2 1/4	127	-	-
18	2	131	2 1/2	168	-	-
21	2 1/4	171	2 3/4	214	-	-
24	2 1/2	217	3	264	3 3/4	366
27	2 5/8	255	3 1/4	322	4	420
30	2 3/4	295	3 1/2	384	4 1/4	476
33	2 7/8	336	3 3/4	451	4 1/2	552
36	3	383	4	524	4 3/4	654
42	3 1/2	520	4 1/2	686	5 1/4	811
48	4	683	5	867	5 3/4	1011
54	4 1/2	864	5 1/2	1068	6 1/4	1208
60	5	1064	6	1295	6 3/4	1473
66	5 1/2	1287	6 1/2	1542	7 1/4	1735
72	6	1532	7	1811	7 3/4	2015
78	6 1/2	1797	7 1/2	2100	8 1/4	2410
84	7	2085	8	2409	8 3/4	2660
90	7 1/2	2395	8 1/2	2740	9 1/4	3020
96	8	2710	9	3090	9 3/4	3355
102	8 1/2	3078	9 1/2	3480	10 1/4	3760
108	9	3446	10	3865	10 3/4	4160

Large Sizes of Pipe Tongue and Groove Joint

Internal Diameter inches	Internal Diameter feet	Wall Thickness inches	Average Weight, pounds per foot
114	9 1/2	9 1/2	3840
120	10	10	4263
126	10 1/2	10 1/2	4690
132	11	11	5148
138	11 1/2	11 1/2	5627
144	12	12	6126
150	12 1/2	12 1/2	6647
156	13	13	7190
162	13 1/2	13 1/2	7754
168	14	14	8339
174	14 1/2	14 1/2	8945
180	15	15	9572

inches x 2.54 = cm
lbs x 454 = kg

Concrete pipe is available in 2.44 m (8') lengths, a variety of diameters. and in three wall thickenesses. Wall A is preferable because it is the lightest and makes the pipe easiest to handle. Pipe joints are tongue and grooved and can be joined with mortar or gasket package as well as with O-ring gaskets to form tanks of desired height. Required sections greater than 2.44 m (8') high can be obtained by sawing the concrete into desired lengths, and then stacking them together.

TABLE 38. SOIL STRENGTH AND DENSITY INDICATORS

SOIL STRENGTH

Term	Unconfined Compressive Strength (After Terzaghi and Peck)	Field Test (After Cooling, Skempton, and Glossop)
Very soft	0-0.5 kips per sq. ft.	Squeezes between fingers when fist is closed
Soft	0.5-1.0	Easily molded by fingers
Firm	1.0-2.0	Molded by strong pressure of fingers
Stiff	2.0-3.0	Dented by strong pressure of fingers
Very stiff	3.0-4.0	Dented only slightly by finger pressure
Hard	4.0 or more	Dented only slightly by pencil point

SOIL DENSITY

Term	Relative Density	Field Test
Loose	0-50%	Easily penetrated with 1/2-in. reinforcing rod pushed by hand
Firm	50-70	Easily penetrated with 1/2-in. reinforcing rod driven with 5-lb. hammer
Dense	70-90	Penetrated a foot with 1/2-in. reinforcing rod driven with 5-lb. hammer
Very dense	90-100	Penetrated only a few inches with 1/2-in. reinforcing rod driven with 5-lb. hammer

kips x .454 x 10^{-3} = kg
sq ft x .093 = sq m
in. x 2.54 = cm

Concrete pad details are as follows: 20 cm (8") thick square pads with base dimensions for various tank diameters are as follows:

m	inches	m x m	inches
0.61	24	1.22 x 1.22	48 x 48
0.76	30	1.32 x 1.32	52 x 52
0.91	36	1.42 x 1.42	56 x 56
1.07	42	1.52 x 1.52	60 x 60
1.22	48	1.63 x 1.63	64 x 64
1.37	54	1.73 x 1.73	68 x 68
1.52	60	1.83 x 1.83	72 x 72

Woven wire recinforcement is to be placed near the bottom of the slab. After pouring the slab, but before the concrete gets stiff, the tank is to be placed on the center of the pad and allowed to sink 7.6 cm (3") into the concrete. This will form a water seal at the base. It is very important that the tank be supported in a vertical orientation until setting occurs.

Holes through the concrete tanks for fittings (preferably threaded nipples) can be installed using a chisel. The nipple can then be mortared in. Metal tank fittings can be welded in place.

D. Installation of Column tanks.

1. **Choose a suitable location - be sure that firm ground is chosen to prevent the column from moving.**
2. **Prepare area and pour concrete slab (see previous section for details).**
3. **Allow concrete to partially set and then place column in the pad.**
   Caution: Be sure that the column is supported vertically until the concrete is set. Possible methods would be to place concrete blocks under the column or provide support.
4. **If additional height (for concrete columns only) is necessary, use the following procedure:**
   - **a. Cut column to desired height with a concrete saw.**
   - **b. Place gasket, O-ring or mortar around the groove on the base column.**
   - **c. Put column extensions on top of column and seal cracks with excess mortar (trowel smooth).**
   - **d. Provide extra support around the joint.**
5. **Wooden braces can be used to reinforce the column if necessary.**
6. **Chisel holes through concrete for fittings and mortar connections.**

7.3.4 Collapsible Rubber Tanks

These tanks are very handy for treatment systems effluent storage and backwash storage. They are typically available in neoprene and Buna-N in sizes ranging from 1.89 - 37.85 cu m (500-10,000 gal.). The tanks come fitted with inlet and outlet fittings. They must be used with a filler vent pipe installed for air venting and to prevent overpressurization. As in other rubber tanks, care must be taken to prevent puncture from sharp objects. A ground cloth or layer of sand is advised.

7.4 PROCESS FLOW COMPONENTS AND FLOW CONTROL

While tanks and pumps are of primary concern in process system construction, process flexibility and control is provided by other components as well, such as piping, hoses, tubing, valves, etc. Selection of these components is of prime importance if the pumps and tanks are to be used effectively. It is impossible in a short space to summarize all of the plumbing devices and installation methods which could be utilized to achieve proper process connections. In almost all localities the availability of plumbing contractors is a valuable resource for expeditious installation of plumbing systems.

This section will provide information on simple connections using hoses and basic control techniques. Plastic piping is also described for use in very corrosive situations. Simplicity is desired in field operations for process flexibility ease of operation and maintenance. However, in terms of safety from hazards, the simplest system may often be the most dangerous. For example, it is probably possible to interconnect processes without the use of valves in many cases. But the constant manual shifting of hoses is a time-consuming and potentially dangerous operation when extremely hazardous materials are being handled. Discretion and good judgment are required in designing a plumbing system which is feasible in the particular situation, as well as being safe.

7.4.1 Hose, Tubing, and Fittings

7.4.1.1 Process Hosing - Hoses for this service can generally be selected according to the following criteria:

a. Suction or discharge (vacuum or pressure)
b. Necessary configuration and use
c. Pressure rating
d. Materials of construction

Information on commercially available hoses are presented in Table 39. Suction hose is very useful in a spill treatment system. It is the most versatile hose in terms of being able to be used interchangeably for suction or discharge in almost any configuration. There is little concern with kinking, however this hose can be damaged by vehicular traffic. It is rather costly and heavy to handle. The hose has excellent availability. Another suction hose which is less available

TABLE 39. COMMERCIALLY AVAILABLE HOSES

Hose Description	Tube Material	Rated Pressure (Psi) / Available Length (Ft.)	Diameter (in.) 1.5	2.0	2.5	3.0	4.0	6.0	Availa-bility
Suction Hose		(Full Vacuum to Positive Pressures as Shown)							
Water Suction	Neoprene	Psi	100	100	100	100	100	50	Excellent
(Rubber cover and tube, wire wound)		Ft.	50	50	50	50	50	20	
Heavy Duty Plastic	PVC	Psi	130*	115	100	85	75	60	Medium
(Black colored)		"	75*	65	65	45	40	35	
		Ft.	60	60	60	60	60	20	
Discharge Hose		(Positive Pressure Only)							
Rubber Discharge (Rubber cover and tube) 4 Ply	SBR/EPR	Psi	250	225	150	125	125	110	Medium
3 Ply	"	"	Not Pressure Rated						
Mill Hose									
Rubber Lined,		Ft.	100	50	50	50	50	50	
Cotton Jacketed	"	Psi.	200	200	200	200	200	200	
(50 Ft. Lengths)		Ft.	50	50	50	50	50	50	Excellent
Synthetic Yarn	PVC	Psi	75	60	55	50	40	40	Medium
Plastic Impregnated		Ft.	300	300	300	300	300	300	

* Pressure rating at 72°F
Pressure rating at 150°F

psi x 703 - kg/sq m
ft x .305 = m
m x 2.54 =cm

but lighter in weight is the plastic suction hose. It is preferred to use the heavy duty variety (often black in color). Pressure ratings are affected by temperature for the plastic hose and it can pull a full vacuum only up to 49°C (120°F). It becomes somewhat stiff at cold temperatures.

Discharge hose is lightweight and inexpensive, but not versatile for use in connecting pumps or treatment processes because of kinking. It becomes very useful for pumping long distances, e.g. raw flow and final effluent discharge. These long runs can be carefully laid and then left uninterrupted. It is desirable to use a short section of suction hose on either end of the long run where connection to a pump or into a tank could product a kink. Of the various types of discharge hoses, mill hose is the most readily available, is economical, and is lightweight.

Process hose support and protection must be handled very carefully. The following are some precautions that should be taken:

1. Tie all free hose ends so that the hose cannot become free or change configuration causing spillage. These supports should be rechecked after hose filling because a hose takes on additional weight when water filled. Tying down hoses is extremely critical when utilizing free discharge into a tank from a diaphragm pump or other type of reciprocating pump. Hose whipping can injure personnel and tank linings as well as spraying contaminated water.

2. When laying suction hoses across areas of vehicle access, the hoses should be either buried or strattled with planks. These planks should be pinned to the ground or otherwise supported to prevent movements. These precautions will prevent wire-wound hoses from crushing and causing flow restrictions.

7.4.1.2 Process Hose Fittings - The following readily available fittings are quite suitable for connecting hoses in field implemented pumping systems. They come with shank ends for mounting to hoses or pipe threads for connecting to process components such as pumps and tanks.

1. Quick couplings - adapter slips into coupler and then is sealed against a gasket by moving two cam-actuated arms; quick to remove and versatile; readily available in brass, alumimum, and cast steel.

2. Pin lug couplings - use a pin lug swivel nut to tighten joint; requires two spanner wrenches; good for hoses which are not often separated during operation; readily available in brass, aluminum, and cast steel.

3. Combination nipples - a shank to pipe thread adapter; for hose pipe thread connections that are typically not removed during the process operation; readily available in cast steel.

7.4.1.3 Process Hose Clamps - Clamps include two basic varieties: one requiring a special tool, such as Band-It or Punch-Lok clamps, and one requiring only a screwdriver or wrench, such as worm gear clamps or two-bolt clamps. The band material is available in coated steel or stainless steel. The clamps requiring the special tools are often better suited for handling of hazardous fluids because of the leverage which can be applied resulting in a strong clamping. It is preferred to use two clamps per hose end to assure trouble-free operation. It is necessary to attach the clamps on the hose shank portion of the fitting.

7.4.1.4 Installation of Fittings on Hoses - The following are recommended steps for field installation of fittings (normally requires two people):

1. Lubricate the shank portion of the fitting and the inside of the hose with a light oil (preferred) or water.
2. Cut the hose off square with a hacksaw. (Wire-wounded hoses can be cut with a hacksaw, but it is somewhat tricky).
3. (Plastic hardwall hose only) Heat the hose end by immersion in hot water for several minutes.
4. Have one person hold the free hose end vertically upright.
5. The second person can install the fitting, and drive it down into place with a hammer or heavy tool. Do not hit the fitting with a metal tool; cushion the blow by placing a piece of wood in-between.
6. Whenever possible, continue to drive on the fitting until the hose contacts the shoulder on the fitting. The main concern is to have several of the shank bars inside the hose for good clamping.

7.4.1.5 Plastic Pipe and Fittings - Although not as readily available as steel piping, plastic piping and fittings are very useful when pumping corrosives, or when forming manifolds for aeration. Available materials include:

1. PVC (Polyvinyl Chloride) - A very strong plastic pipe: maximum service temperature of 60°C (140°F). Excellent chemical resistance to a wide range of corrosive fluids, but may be damaged by ketones, aromatics and some chlorinated hydrocarbons; is joined by solvent welding or threading.
2. CPVC (Chlorinated Polyvinyl Chloride) - Can handle corrosives up to 85°C (185°F). Comparable to PVC in chemical resistance; is joined by solvent welding or threading.
3. Penton (Chlorinated Polyether) - Very good chemical resistance and is useful up to 121°C (250°F). Costs two to three times as much as PVC piping and is used for elevated temperatures or where other

materials lack satisfactory resistance to specific chemicals; is joined by threading.

4. Polypropylene - Finds wide application in pumping mixtures of acids, bases, and solvents; may be used up to 82°C (180°F); is best joined by Thermo-Seal fusion welding.

A variety of fittings, e.g. elbows, tees, couplings, reducers, flanges, etc. are available in both threaded and socket types. Local stocking of pipe and fittings, however, will probably be limited to PVC products.

Plastic piping is installed to look very much like metal piping systemswith the difference that closer support spacings are required.

The following is a brief description of joining methods for plastic pipe:

1. Solvent Welding - The generally preferred method of joining rigid thermoplastics such as PVC and CPVC, is solvent welding. This gives a stronger joint than threading and is also considered faster and simpler. Additionally, solvent welding permits the use of thinner walls, when compared to threaded connections, for equivalent pressure ratings.

2. Threading - As is the case with metal pipe, threading reduces the effective wall thickness of thermoplastic pipe and introduces notch effects which lower strength. Threaded connections should be used with Schedule 80 or heavier pipe. The chief advantage of threading is the ease of disassembly it offers.

3. Thermal Bonding - By taking advantage of the thermoplasticity of the materials, methods of joining solvent-resistant thermoplastics such as polypropylene are available which utilize tools to apply regulated heat uniformly and simultaneously to pipe and fitting mating surfaces so that true melting occurs on the surfaces. Only hand pressure is needed to join the components and as the material cools, a permanent homogenous bond results.

4. Flanging - One of the earliest methods for joining thermoplastic piping, flanging continues to be used extensively for process lines. Thermoplastic flanges and flanged fittings are available in a full size range and may be attached to pipe by solvent welding, by threading, or by thermal bonding, as required by the particular thermoplastic material.

7.4.2 Flow Control

Tanks, pumps, hoses, and fittings constitute the primary means to store, move, and treat fluids in field implemented process systems. However, because not all pumps are variable speed controlled, and because treatment processes involve flow diversions to accomodate the various process modes, valves or other flow control devices will probably be required in most treatment systems. If they are not required for flow control, they are desirable from the standpoint of safety. For example, when treating hazardous fluids, it is preferred from a safety standpoint, to open or close a valve rather than manually changing hose locations and connections. In this manual, no attempt was made to devise valving systems to eliminate hose transfers in the various process modes. Since the local availability of valves is unknown, it would be advisable for the On-Scene Coordinator to have the services of a person versed in design and construction of plumbing systems for hookups.

The following are flow control techniques which can be employed in field treatment systems:

1. Pump speed control - flow control may be inherent in speed controls which are built in the pump-drive system itself. For example:

   a. Engine driven pumps - engine throttling is used to alter pump speed and thus control flow;

   b. Air-driven pumps - control of air flow is used to regulate fluid flow;

   c. Variable-speed electric pumps - mechanical linkages between motor and pump allow variable drive ratios which alter pump speed and change flow.

2. Changing of pump head-Most direct-coupled electrical pumps, however, will be constant-speed devices and require changes in pressure head to control flow. A variety of pump head control techniques are possible:

   a. Throttling valve control - head loss across the valve is increased or decreased by opening or closing a valve on the discharge side of the pump; a continuous control technique.

   b. Sizes and length of hoses - excess or undersized hosing can alter total friction head and cause flow changes; system must be shutoff and drained. Should be performed on discharge side of pump only.

   c. Changes in static head - changing the location of the receiving water level with respect to the pumping water level; (changing the location of the pump alone will not effect a static head change). System would be shutoff for this change.

3. Bypass systems - Flow control may be achieved by bypassing some of the fluid from the discharge side of the pump either back to the suction side or back to the pumping water body. This can be done without any valves through controlling relative sizes of

flow and bypass lines (not a continuous control technique) or a bypass valve may be installed for continuous flow control.

7.4.2.1 Valves (see Reference 62) - Valve function, more than any other single criterion limits the choice of valves. For purposes of discussion, valves may be categorized into three groupings: on-off service, throttling service, and prevention of backflow. Pressure drop through valves can be substantial and so a valve selection which minimizes pressure drop while still meeting other requirements is obviously best. Valves are available in a variety of materials of construction to be compatible with corrosive environments. Materials of construction, however, are sometimes limited to certain sizes. For example, in water service, valves up to 10 cm (4") size are generally available in brass or bronze, whereas in sizes above 10 cm (4") iron and steel bodies are usually available. Small sizes, up to about 5 cm (2") are screwed and the larger sizes flanged.

Care must also be taken in choosing valves for field treatment processes to select a valve which will not clog easily from debris. Few field processes are free of materials which can clog valves and disrupt system flow.

Varieties of the valve groupings are described below:

1. On-Off Service - Gate, plug, ball, and butterfly valves; gate valves are the most readily available; full port valves are best suited for field treatment processes; plug and ball valves come in venturi and reduced port designs which have increased pressure losses and susceptability to clogging; not generally good for throttling because the valve is almost closed before pressure begins to rise; in the almost closed position the full port feature is useless. Butterfly valves, good for on-off or throttling service, are described in the next section.

2. Throttling Service -

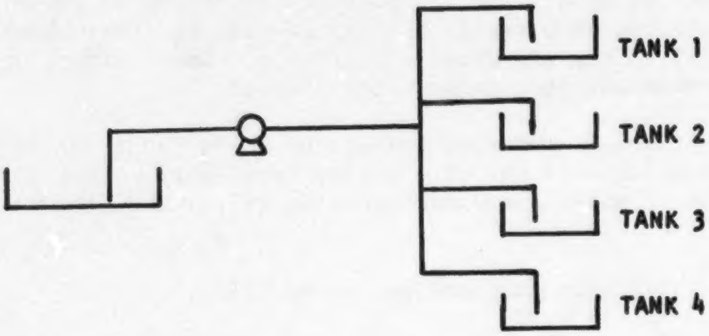
   a. Globe valve - unidirectional valve; high pressure drop due to tortuous flow path; Y-pattern and angle-pattern help to minimize pressure loss;

   b. Butterfly valve - built like a stovepipe damper; screwed pipe connections on small sizes (up to 2 inch), wafer design on larger sizes requires mounting between two flanges; low pressure loss; especially well-suited for large flows; quite suitable for slurries or solids-bearing liquids; fast acting;

   c. Diaphragm valve - most commonly available in weir pattern; pressure drop roughly equivalent to globe valve; no packing required because of complete fluid isolation; excellent for viscous media, slurries, and corrosive fluids.

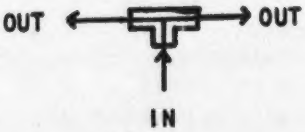
3. Check Valves - prevent reverse flow in fluid line; automatic in operation; are kept open by the pressure of the flowing fluid; available in swing, tilting disc, lift, or stop-check designs' of the four varieties, swing and tilting disk have the straight flow pattern and lowest pressure loss.

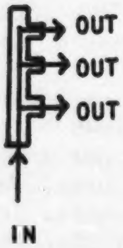
7.4.2.2 Flow Splitting - Because of limited availability of valves and the need to divide flow from a single pump discharge into a number of parallel treatment processes, a flow splitter is required such as is shown schematically below.

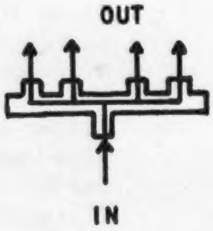


The flow splitter is basically a plumbing manifold with a single inlet and multiple outlets. It can be constructed from either screwed plumbing fittings or as a weldment. Below are listed some criteria to be used when designing a flow splitter:

1. Make the fitting as symmetrical as possible from inlet to outlet without making one flow path easier than another.



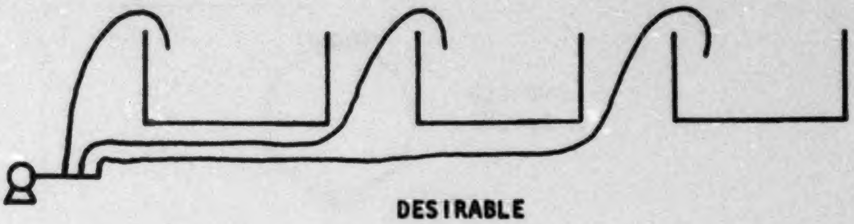




e.g. for the two, three and four outlet manifolds shown above all flow lines from in to out involve the same number of bends.

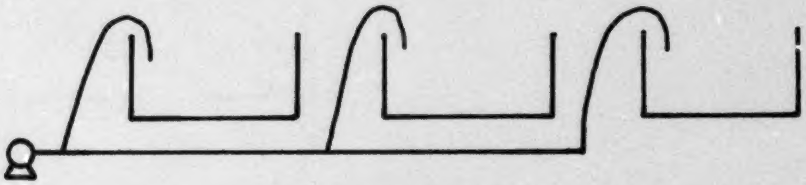
2. Make the total length of the manifold as short as possible.

a.



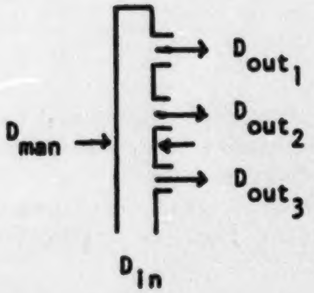
DESIRABLE

b.



UNDESIRABLE

3. The total area of outlet should be less than the manifold area.



$$\frac{\pi D^2_{man}}{4} > \frac{\pi}{4}\left(D^2_{out_1} + D^2_{out_2} + D^2_{out_3}\right)$$

or, generally

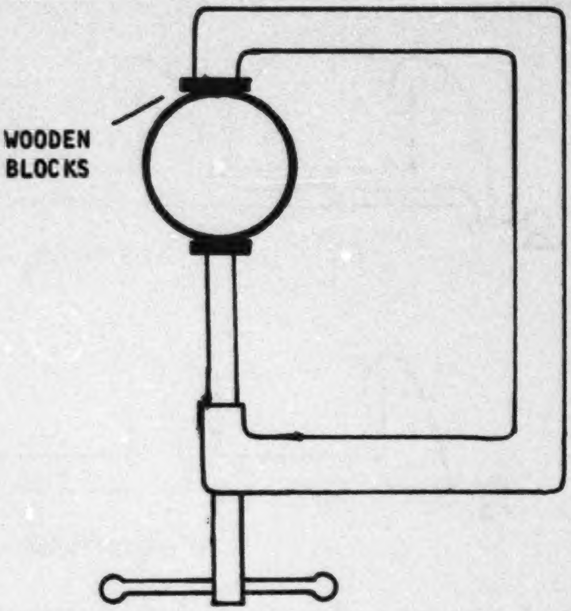
$$D^2_{man} > D^2_{out_1} + D^2_{out_2} \cdots D^2_{out_n}$$

Note: The manifold area may be enlarged above the inlet area to meet this requirement.

4. Do not support heavy manifolds from a pump body. A length of lead hose to a manifold lying on the ground is preferred.

If the flow splitter does not provide as equal a division of flow as in desired without the use of valves, some further flow equalizing techniques may be employed:

1. Varying the discharge elevations of the outlets.
2. Using the longer discharge hoses on the higher flowing lines.
3. Crimping a hose to cause flow restriction, e.g. using a C-clamp valve as shown below in an end view.



7.5 CHEMICAL FEED COMPONENTS

7.5.1 General

Equipment which is necessary to safely handle the treatment chemicals is considered separately in two subsections. These chemicals are unsafe to handle using improvised systems due to their high concentrations and corrosive properties. Therefore, specialty equipment manufactured specifically for handling of these chemicals must be obtained locally by the OSC and transported to the treatment site.

The descriptions which follow are intended to provide a basic understanding of the types of available chemical feed pumps, tubing fittings and mixers. This type of equipment is usually handled by suppliers who have ready access to information from which the best equipment for the particular application may be selected. To contact suppliers for a local area, the Yellow Pages should be consulted under the following, or similar subjects:

Hose and Tubing - Rubber and Plastic
Laboratory Equipment and Supplies
Mixing and Agitation Machinery
Pumps
Tanks -Fiber Glass, Plastic, etc.
Tube Fittings
Tubing - Metal

Since the suppliers have the needed expertise, no attempt has been made to specify the best components for a certain chemical. This specification may limit the OSC to a certain suitable but unavailable type of equipment, and thereby halt the treatment operation. Instead, a list of information needed to establish the suitable equipment type has been presented. (see Figure 75) To use this approach, the OSC should complete the charts and then relay this information to the supplier. Then the supplier can recommend the equipment needed.

7.5.2 Chemical Metering Pumps

Chemical feed pumps are normally available at pump supply houses. To facilitate selection of chemical feed pumps, available pumps are classified into the following three general headings. These headings differentiate between the different pumping actions and permit identification of wetted parts which is important when selecting proper materials of construction. The classification designating A-C are used in other parts of the manual when referring to these pumps:

> Type A. Centrifugal, positive pressure, and gear pumps: Type A pumps are not positive displacement pumps which means that pumping volume is not independent of pressure. Thus they are not normally used where exact metering is critical under all conditions. For most applications though, where pressure does not fluctuate dramatically, reasonably accurate calibrations can be achieved.
>
> The centrifugal or gear pumps are suitable for pumping chemical solutions at higher flow rates (typically 3.7 - 170 lpm (1-45 gpm)) and low to medium pressures (typically up to 1.3 atm (20 psi). They are not self-priming and should be operated with a flooded suction. The positive pressure pumps are capable of pulling suction lifts of 0.9-48 m (3-15 ft) dry and 6.1 - 7.6 m (20-25 ft) primed. They also are suitable for higher flows (typically 3.7-98 lpm (1-26 gpm)) and low to medium pressures (typically up to 3.4 atm (50 psi).
>
> They have impellers or gears which rotate at constant or variable speed. The impellers may be rigid members rotating with a clearance within the pumping chamber; they may be gears or lobes which mechanically mesh; or they may be flexible impellers which have contact with the pumping chamber as they rotate. The pumps are either direct drive, in which case there is a seal around the drive shaft to prevent corrosion of the motor, or magnetically coupled, in which the drive end is completely independent of the fluid end and no shaft seal is necessary. Typical materials of construction for the wetted parts of Type A pumps are listed in Table 40.
>
> Type B. Reciprocating, Positive Displacement Pumps: These pumps are capable of producing a fixed or variably controlled output flow irrespective of system pressure. They are most accurate with a flooded suction and high pressure outlet (typically 40 psi). In low pressure systems this outlet pressure can be created artificially with a backpressure valve.

Required information for Establishing Suitable Chemical Feed Equipment.

Pumps

1. What is the required flow rate? ____________

2. What chemicals and concentrations are to be pumped*

Chemicals	Concentrations
____________	____________
____________	____________
____________	____________

* One chemical may be pumped at various concentrations so specify both.

3. What suction lift is required (See 7.2.1)? ____________

4. What discharge head is required (See 7.2.1)? ____________

5. Is flow adjustment needed during operation? ____________

6. At what temperatures will the pump operate? ____________

7. What electrical requirements exist?

Voltage ______ single
3 phase

Tubing and Fittings

1. What sizes are needed (Tube O.D.)? ____________

2. What will be the operating pressure? ____________

3. What materials and concentrations are to be pumped? (See pump section) ____________

4. What are the thread specifications for connected parts? ____________

e.g. nominal size of NPT pipe, threads, male or female threads, etc.

Figure 75 Information needed to obtain suitable chemical feed equipment

Tanks

1. What volume is needed? __________
2. What materials and concentrations are to be contained? __________
3. What mixer mount is needed?

   side, center, other
4. Where are fittings to be located and what size is needed?
5. Is the tank to be covered?

Mixers

1. What materials and concentrations are to be mixed?

   __________________ __________________

   __________________ __________________

   __________________ __________________
2. How long will the mixer operate per batch? __________
3. How many batches will be mixed per day? __________
4. What is the tank volume and dimensions? __________
5. What type of mixing is required?

   Rapid mix

   Gentle mix
6. What electrical hookups are available?

   Voltage Single

   3 phase

Figure 75 (continued). Information needed to obtain suitable chemical feed equipment

TABLE 40. MATERIALS OF CONSTRUCTION FOR TYPE A PUMPS

Body	Impeller	Shaft	Seal
Centrifugal (Capacities 25-170 lpm (6.6-45 gpm), maximum pressure .2-1.5 kg/cm^2 (4-21 psi)			
polyethylene	polyethylene	stainless steel	Buna N and stainless steel
nylon	stainless steel	nitrile coated steel	
stainless steel			Buna N
polypropylene	polypropylene		Carbon or none required for magnetic drive
Buna N	Buna N		
Penton	Penton		
Positive Pressure (Capacities 11-98 lpm (3-26 gpm)			
	nitrile	stainless steel	neoprene
bronze	neoprene	Hastelloy "B" and "C"	Buna N
stainless steel	viton	Titanium	Carbon & stainless
phenolic	epoxy		Nitrile
epoxy	Buna N		Viton or none required
Gear			
stainless steel	stainless steel	stainless steel	neoprene or none required
delrin plastic	teflon		

By utilizing micrometer-adjusted mechanical and hydraulic control linkages, these pumps are capable of accurately metering fluids from high flows down to a fraction of a gph. They can also pump against very high pressures.

There are two basic types of positive displacement pumps - plunger pumps and diaphragm pumps. It is only important here to note that they represent differences in the types of wetted parts: the plunger pump with a piston and packed seal and the diaphragm pump with a flexible displacement element. Both pumps require inlet and outlet check valves to allow the fluid to be pumped. Typical materials of construction for the two types of pumps are as follows: (Table 41)

Type C. Peristaltic and Flexible-stator, eccentric-rotor pumps: These pumps employ a squeegee action to pump the fluid. They are thus positive pressure, rather than positive displacement pumps. They differ from Type A pumps because there is no impeller in the fluid stream. Rather the rotational action is transmitted into a progressive squeezing on either a tube section or a flexible liner within the pump head. The peristaltic or tube-squeezing pump is utilized for flow metering

TABLE 41. MATERIALS OF CONSTRUCTION FOR POSITIVE DISPLACEMENT PUMPS

Plunger pump			Diaphragm pump	Check valves		
Pump body	Plunger	Lantern ring	Diaphragm or bellows	Valve Body	Ball	Ball seat
steel	stainless steel	stainless steel	elastometer	steel	stainless steel	stainless steel
iron	ceramic	Allow 20	teflon	stainless steel	PVC	PVC
stainless steel	monel	Hostelloy "C"	polyethylene	PVC	Hostelloy "C" to "D"	Alloy 20
PVC		PVC	Buna N	Allow 20	alumina-ceramic	monel
Alloy 20		alumina-ceramic	neoprene	Hostelloy "C"		Hostelloy "C"
Monel			Viton	monel		
Carpenter 20			resistant steels			

at flows less than 1 gpm and pressures to 1.7 atm (25 psi) under continuous use. The flexible stator pump has a capacity range of from 1.1 - 15 lpm (0.3-40 gpm) at up to 2.4 atm (35 psi) continuous pressure. Both pump types are self-priming and both pumps are susceptible to tube or liner failure after extended use.

The wetted parts used in typical Type C pumps are listed as follows:

Pump body	Peristaltic tubing	Flexible stator liner
polyethylene	tygon	gum ribber
teflon	viton	Buna N
bakelite	silicone	neoprene
stainless steel		hypalon
		butyl
		viton

7.5.3 Thermoplastic Tubing and Fittings

Thermoplastic tubing and fittings are perhaps the most versatile for field hookups of chemical feed systems, particularly because of their flexibility and ease of assembly. They are suitable for use with a wide range of chemicals. Typical sizes and ratings are given in Table 42.

Thermoplastic fittings can also connect tubing constructed of the following materials: copper, brass, steel, stainless steel, glass, plastic, aluminum.

7.5.3.1 Thermoplastic Insert Fittings - Polyethylene or nylon shank fittings (require clamps) can be used with either reinforced or non-reinforced clear vinyl plastic hosing or rubber hosing in the 0.5-5 cm (3/16 - 2 in.) inside diameter range and at working pressures up to 8.5 atm (125 psi). Clear vinyl tubing and hosing can be obtained in a variety of wall thickenesses for use with these insert fittings, providing a wide range of pressure ratings.

7.5.3.2 Metal Tubing and Fittings - Metal tubing fittings are available in brass, stainless steel, steel, and aluminum typically in sizes from 0.17 - 2.5 cm (1/16 - 1 in.) O.D. They can be used with steel, stainless steel, copper, aluminum, glass, and plastic tubing. Many types require only wrenches to install. However, tube cutting and bending devices are desirable when using metal tubing.

7.5.4 Chemical Feed Tanks

Several varieties of polyethylene and fiberglass tanks are available out of stock from the manufacturers. The most readily available are flat bottom, open top tanks in the 0.23-1.7 cu m (60-450 gal.) range. Also available but probably not from stock are dished bottom, open top tanks, with bottom fittings to accommodate filling and emptying. Concrete tanks, such as septic tanks or tanks constructed from sewer tiles as described in Section 7.3.3 can also be used to mix and store chemicals.

TABLE 42. TYPICAL THERMOPLASTIC TUBE SIZE

	Pressure rating, psi	Lengths, ft	Outside diameter, in.
polypropylene (rigid)	190	10	3/8, 1/2, 5/8
nylon	250	500	1/8, 3/16
	250	250	1/4, 5/16, 3/8, 1/2
vinyl (clear)	65	50	1/4
(formula PV-1 or PV-2)	55	50	5/16, 3/8
	45	50	1/2
	30	50	5/8
polyethylene	120	1000	1/4
	145	500	5/16
	125	500	3/8
	90	250	1/2
	70	100-500	5/8

Fittings - nylon and polypropylene

pressure ratings - Tube O.D.	Working Temperature, °F up to 75	76-125	126-175
1/4	300	300	300
5/16	300	300	300
3/8	250	250	150
1/2	200	200	150
5/8	150	100	50

available fittings: unions, connectors for tubing to male or female pipe threads, tees, reducer unions, elbows

psi x .068 - atm
feet x 0.305 = m
meters x 2.54 - cm
(°F - 32) x 5/9 = °C.

7.5.5 Chemical Feed Mixers

Impeller mixers, both direct drive and gear drive are available, although the gear drive operating at about 350 rpm is more suitable for chemical mixing. The shaft length and number and configuration of impellers must be based on the geometry of the chemical tank. Portable mixers are usually equipped with clamp mounts and ball and socket index positioning joints. Stainless steel, Type 316, shaft and impellers are typically used on chemical service, with rubber covering used on some severe corrosives such as ferric chloride.

Power requirements range from .18 - 2.2 kw (1/4 - 3 HP) are available and the following preliminary sizings are presented for reference:

1. For dissolving chemicals and mixing acids and bases - .25 kw for 1,893 ℓ tank, and .56 kw for a 3,785 ℓ tank (1/3 hp for 500 gallon tank, 3/4 hp for 1000 gallon tank).
2. For mixing polyelectrolytes or lime - .56 kw for a 1,893 ℓ and 1.2 kw for a 3,785 ℓ tank (3/4 hp for 500 gallon tank, 1 1/2 hp for 1000 gallon tank.

7.6 AIR COMPRESSORS AND BLOWERS

The typical uses for air in field implemented treatment operations are for use on air driven diaphragm pumps and for aeration. The most readily available compressor is the rotary screw compressor, which is a constant volume device, capable of pressure control down to 4 atm (60 psi). In applications such as aeration where pressures less than .34 atm (5 psi) are required, an additional pressure regulator and flow bypass valve will be needed to provide flow control. Table 43 summarizes potential sources of air compressors and blowers.

7.7 SELECTION OF CORROSION RESISTANT MATERIALS OF CONSTRUCTION

This subsection provides information on the various materials of construction which are available. Included is information regarding trade names, corrosion resistances and typical uses of both ferrous and non-ferrous metals and other nonmetallic materials. The general corrosion resistance properties are discussed. In most spill situations, the flow stream will contain only diluted contaminants so corrosion problems will be minimal. The most corrosive materials are the treatment chemicals and special types of chemical feed pumps and components must be obtained. It is recommended that the user contact the manufacturers of various equipment, detail the specific conditions of the contaminated water and treatment chemicals and then choose the type of materials needed. This section will then allow the user to augment his knowledge of the materials involved and check the recommended application. The material presented is summarized in most part from "Corrosion Engineering" written by M. G. Fontana and N. D. Green (63). Further information regarding materials is available in this text and other references.

7.7.1 Metals

1. Cast iron - This material is found in many cast process components such as pump bodies, impellers, valve parts, etc. Cast iron is a general term applied to high carbon-iron alloys containing silicon. Common varieties are: gray, white, malleable, ductile, and nodular. The material is quite susceptible to oxidation or "rust".

   Increasing the silicon content to over 14% produces an extremely corrosion resistant material, e.g. Duriron, which is very hard and resists erosion-corrosion (notable exception: hydrofluoric

TABLE 43. SOURCES AND SIZES OF AIR COMPRESSORS

Air Compressors:

Sources	Size	Pressures	Comments
Contractor Supply House	150-650 scfm	100-125 psig	Low capacity are gas engine powered and higher capacity are diesel engine powered. Require pressure regulators to give lower delivery pressures. Can normally be rented.
Local Sewage Treatment Plant	150-650 scfm	100-125 psig	
Local DPW	150-650 scfm	100-125 psig	
Fire Dept.	150-650 scfm	100-125 psig	
Manufacturers of Blowers	Wide range of sizes	Low pressure up to 15 psi	Generally must be purchased.

scfm x .028 = scum/min.
psi x .068 = atm

acid). The alloy is sometimes modified by the addition of 3% molybdenum, e.g. Durichlor or Durichlor 51, for increased resistance to hydrochloric acid and chlorides.

In addition to alloys using silicon and molybdenum, other alloys using nickel, chromium and copper also produce improved corrosion resistance. Copper addition causes the metal to better withstand attack from sulfuric acid. High nickel-chromium cast irons with and without copper, e.g. Ni-Resist and Ni-Hard, produce very tough castings to resist erosion-corrosion in near-neutral and alkaline solutions or slurries.

2. Carbon steel - Carbon steel is alloyed, in various combinations, with chromium, nickel, copper, molybdenum, phosphorous, and vanadium. Low-alloy steels (2% total maximum alloying elements or less) are generally the more corrosion resistant. However, like cast iron, it is very susceptible to rusting.

   Steel products are cast and also readily available in sheet, plate, and structural forms, as well as in a variety of products. Steels can be easily field cut and welded.

3. Stainless Steel - Stainless steel has the same versatility of usage as carbon steel, with greatly improved corrosion resistance. Desired corrosion resistant properties are produced by alloying at least 11 percent of chromium. The chromium is reactive, but sets up a passive film to inhibit further corrosion.
   The following (64) is a brief description of the five types of corrosion resistant alloys most commonly used in chemical applications:

Type 304	The basic 18% Cr-8% Ni type for relatively mild corrosion resistance.
Type 316	The "18-8" type with 2.0/3.0% Mo for superior resistance to pitting and to most types of corrosion, particularly in reducing and neutral solutions.
Type 317	The "18-8" type with 3.0/4.0% Mo, which has moderately better resistance than type 316 in some conditions, such as high concentrations of acetic anhydride and hot acetic acid.
"20"	A 29% Ni-20% Cr steel with copper and molybdenum, developed specifically for resistance to sulfuric acid.
Ni-o-nel	A 42% Ni-21.5% Cr alloy with copper and molybdenum, developed to meet more severe corrosion and stress-corrosion conditions than can be handled by the stainless steels but where nickel-base alloys are not needed.

4. Aluminum and Alloys - Next to carbon steel and stainless steel, aluminum represents a versatile metal for construction, available in cast form and sheet, plate, and structural forms and in a variety of commercially available process components.

   Aluminum is reactive but develops a passive oxide film which protects it from further corrosion in many environments. This film remains stable in neutral and many acid solutions, but is attacked by alkalies. The passive film is produced after contact with the chemical environment, unless the film has been artificially produced through anodizing. Structural members are typically produced from high-copper alloys, whereas process components are usually constructed of the low-copper or copper-free alloys, which have better corrosion resistance.

5. Magnesium and Alloys - A lightweight material often found on portable devices and vehicles, however one of the least corrosion resistant. It must generally be physically separated from other metals or it will become a sacrificial anode for them. It is capable of forming a good passive film, however, the film breaks down in salty air conditions, necessitating that special coatings or other surface preparations be used. Magnesium is susceptible to erosion-corrosion. It is much more resistant to alkalies than is aluminum. It is attacked by most acids except chromic and hydrofluoric. The corrosion product in HF acts as a protective film.

6. Lead and Alloys - Used often on corrosion resistant applications in such forms as : sheet linings, solder, cable sheath, bearings, and piping. Lead forms protective films consisting of corrosion products such as sulfates, oxides, and phosphates. It is subject to erosion-corrosion because of its softness. Chemical-resistant lead, containing about 0.06% copper, is resistant to sulfuric, chromic, hydrofluoric, and phosphoric acids, neutral solutions, and seawater. It is rapidly attacked by acetic acid and generally not used in nitric, hydrochloric, and organic acids.

7. Copper and Alloys - Copper alloys are found in pump bodies and impellers, process component bodies and parts, and in pipe tubing and fittings, tanks, bearings, wire and screen.

   A good chemically resistant material, copper is a noble metal and is not corroded by acids unless oxygen or other oxidizing agents (e.g. HNO_3) are present. Copper-base alloys are resistant to neutral and slightly alkaline solutions (exception: ammonia). Common alloys are: brass, bronze, and cupernickel. Bronze. aluminum brass, and cupranickel are stronger and harder than copper and brass and less subject to erosion-corrosion.

8. Nickel and Alloys - A workhorse in severe corrosion applications, nickel and its alloys are found in many commercially available

process components, especially pumps, valve parts, and other critical process parts. Nickel is resistant to many corrosives and is a natural for alkaline solutions, found in many tough applications on caustics. It shows good resistance to neutral and slightly acid solutions. It is not resistant to strongly oxidizing solutions, e.g. nitric acid, ammonia. Among the common varieties:

Monel - natural for hydrofluoric acid

Chlorimet 3 and Hastelloy C - two of the most generally corrosion-resistant materials commercially available

Chlorimet 2 and Hastelloy B - very good in cases where oxidizing conditions do not exist

9. Zinc and Alloys - Not a corrosion-resistant metal, chiefly used in galvanized steel.

10. Tin and Tin Plate - Usually found as a coating and is used in solder and babbit bearings, is corrosion resistant, easily formed and soldered; and provides a good base for organic coatings. Tin has good resistance to dilute mineral acids in the absence of air, and many organic acids, but is corroded by strong organic acids; generally not used for handling alkalies.

11. Titanium and Alloys - A newcomer to corrosion resistant construction, is available as castings in pumps, valves, and other process components. Titanium is a reactive metal which depends on a passive oxide film for corrosion resistance. Titanium has resistance to seawater and other chloride salt solution; hypochlorites and wet chlorine; and nitric acid. Salts such as $FeCl_3$ and $CuCl_2$, which tend to pit other metals do not corrode titanium. It is not resistant to relatively pure sulfuric and hydrochloric acids.

7.7.2 Nonmetallics

1. Natural and Synthetic Rubbers - Rubber is an important process material with an extensive range of uses: hoses, tanks, tubing, gaskets, pump diaphragms and impellers, sheets, liners, etc. Rubber has excellent chemical resistance, and has been a standard for handling of hydrochloric acid. Generally, the synthetic rubbers have better chemical resistance than the natural rubbers. Vulcanization, the process of hardening rubber by adding sulfur and heating, can produce a wide range of hardnesses from soft gaskets to hard pump impellers. Corrosion resistance generally increases with hardness.

   A wide variety of synthetic rubbers is available, including combinations with plastics. In developing the various products, plasticizer fillers and hardeners are compounded to obtain a large range of properties, including chemical resistance.

Table 44 shows chemical resistance and other properties of commercially available rubber products. One of the newer elastomers which should be added to the list is Hypalon, which has excellent resistance to oxidizing environments such as 90% sulfuric acid and 40% nitric acid at room temperature.

2. Plastics - Used extensively in chemical process applications as process component bodies and parts, tanks and tank liners, pipe, valves, tubing, and fittings, sheets, structurals, etc., plastics are high-molecular weight organic materials that can be shaped into a variety of useful forms.

When comparing plastics to metals, the former are softer and weaker, more resistant to chloride ions and hydrochloric acid, less resistant to concentrated sulfuric and oxidizing acids such as nitric, less resistant to solvents, and have definitely lower temperature limitations.

Plastics, when subjected to corrosive environments do not fail as metals do. Rather than dissolving, they are degraded or corroded because of swelling, loss in mechanical properties, softening, hardening, spalling, and discoloration. Table 45 lists the properties of some commercially available plastics.

For ease of using this table, commonly used tradenames and other designations are listed here alphabetically in reference to the chart classification to which they belong:

Material	Chart Classification
Aeroflex	Polyethylene
Alathon	Polyethylene
Araldite	Epoxy
Avisco	Urea
Bakelite	Phenolic
Beelte	Urea
Dacron	Polyester
Durcon	Epoxy
Durez	Phenolic
Dypol	Polyester
Epon	Epoxy
Excon	Polypropylene
Kel F	Fluorocarbon
Lauxite	Urea
Lucite	Methyl methacrylate
Lustrex	Polystyrene
Moplen	Polypropylene

TABLE 44. PROPERTY COMPARISONS - NATURAL AND SYNTHETIC RUBBERS (63)

Property	Natural rubber	Butyl (GR-I)	Buna S (GR-S)	Neoprene	Nitrile (buna N)	Polyacrylic rubber	Silicone rubber
Hardness range (Shore "A") [a]	40-100	40-90	40-100	30-90	45-100	50-90	40-80
Tensile strength, psi [b]	4500	3000	3500	3500	4000	1500	900
Max. elongation, %	900	900	600	1000	700	200	250
Abrasion resistance [c]	Excellent	Good	Excellent	Very good	Excellent	Fair	Poor
Resistance to compression set at 158°F [c]	Good	Fair	Excellent	Good	Excellent	Good	Excellent
Resistance to compression set up to 250°F [c]	Poor	Poor	Excellent	Fair	Excellent	Good	Excellent
Aging resistance (normal temp.)	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Max. ambient temp. allowable, °F	160	275	275	225	300	400	580
Resistance to weather and ozone [c]	Fair	Very good	Fair	Excellent	Fair	Excellent	Excellent
Resistance to flexing	Excellent	Excellent	Good	Excellent	Fair	Excellent	Poor
Resistance to diffusion of gases	Fair	Excellent	Fair	Very good	Fair		
Resilience	Excellent	Poor at low temp. Good at high temp.	Fair	Very good	Fair	Poor	
Resistance to petroleum oils and greases	Poor	Poor	Poor	Good	Excellent	Very good	Good
Resistance to vegetable oils	Good	Good					
Resistance to non-aromatic fuels and solvents	Poor	Poor	Poor	Fair to good	Very Good		Fair
Resistance to aromatic fuels and solvents	Poor	Poor	Poor	Fair	Good		Poor
Resistance to water and anti-freezes [c]	Good	Good	Good	Fair	Excellent	Poor	Fair
Resistance to dilute acids	Good	Good	Good	Good	Good		
Resistance to oxidizing agents	Poor	Fair	Poor	Poor	Poor		
Resistance to alkali	Fair	Fair	Fair	Good	Fair		
Dielectric strength [c]	Excellent	Good	Excellent	Fair	Fair		
Flame resistance	Poor	Poor	Poor	Good	Poor		
Processing characteristics	Excellent	Good	Good	Good	Good	Fair	Poor
Low temp. resistance [c]	Very good	Fair	Good	Fair	Good	Poor	Excellent
Tear resistance	Excellent	Excellent	Good	Good	Good	Fair	Poor

[a] 100 Durometer reading is bone hard and indicates that ebonite or hard rubber can be made.

[b] Indicates soft-rubber type. Hard-rubber types run higher in value.

[c] These properties available in specific compounds.

TABLE 45. PROPERTIES OF COMMERCIALLY AVAILABLE PLASTICS (63)

Material	Acids		Alkalies		Organic solvents	Water absorption, %/24 hr	Oxygen and ozone	High vacuum	Ionizing radia-tion	Temperature Resistance	
	Weak	Strong	Weak	Strong						High	Low
					Thermoplastics						
Fluorocarbons	Inert	Inert	Inert	Inert	Inert	0.0	Inert	-	P	550	G-275
Methyl methacrylate	R	A-O	R	A	A	0.2	R	decomp.	P	180	-
Nylon	G	A	R	R	R	1.5	SA	-	F	300	G-70
Polyether (chlorinated)	R	A-O	R	R	G	0.01	R	-	-	280	G
Polyethylene (low density)	R	A-O	R	R	G	0.15	A	F	F	140	G-80
Polyethylene (high density)	R	A-O	R	R	G	0.1	A	F	G	160	G-100
Polypropylene	R	A-O	R	R	R	<0.01	A	F	G	300	P
Polystyrene	R	A-O	R	R	A	0.04	SA	P	G	160	P
Rigid polyvinyl chloride	R	R	R	R	A	0.10	R	-	P	150	P
Vinyls (chloride)	R	R	R	R	A	0.45	R	P	P	160	-
					Thermosetters						
Epoxy (cast)	R	SA	R	R	G	0.1	SA	-	G	400	L
Phenolics	SA	A	SA	A	SA	0.6	-	-	G	400	L
Polyesters	SA	A	A	A	SA	0.2	A	-	G	350	L
Silicones	SA	SA	SA	SA	A	0.15	R	-	F	550	L
Ureas	A	A	A	A	R	0.6	A	-	P	170	L

NOTE: R = resistant, A = attacked, SA - slight attack, A-O = attacked by oxidizing acids, G = good, F - fair, P = poor, L = little change.

Mylar	Polyester
Nylon	Nylon
Penton	Polyether
Plexiglas	Methyl methacrylate
Plioflex	Vinyl
Polythene	Polyethylene
Pro-Fax	Polypropylene
PVC	Polyvinyl chloride
Resinox	Phenolic
Saran	Vinyl
Styron	Polystyrene
Teflon	Fluorocarbon
Tygon	Vinyl
Vibrin	Polyester
Vinylite	Vinyl
Viton	Fluorocarbon

3. Other Nonmetallics - Used as materials of construction and lining of process systems:

Ceramics - compounds of metallic and non-metallic elements; include magnesia, brick, stone, fused silica, stoneware, glass, clay tile, porcelain, concrete, abrasives, mortar, high temperature refractories. Most ceramics exhibit good chemical resistance, with the exception of hydrofluoric acid and caustic.

Carbon and Graphite - often used for shaft seals; inert to many chemical environments; good resistance to alkalies and most acids; attacked by oxidizing acids such as nitric, concentrated sulfuric, and chromic; also attacked by fluorine, iodine, bromine, chlorine, and chlorine dioxide.

Wood - Typical chemically resistant woods are cypress, pine, oak, and redwood; generally limited to dilute chemicals; strong acids, oxidizing acids, and dilute alkalies attack wood.

7.7.3 Protective Coatings

Paints, varnishes, lacquers, and similar coatings are capable of preventing corrosive attack of the substrate material when they are properly selected and correctly applied. Three main areas of concern are surface preparation, and selection of primer and top coat.

1. Surface preparation - involves removal of dirt, rust, mill scale, oil, grease, and other impurities. Surface should be roughened to give a good mechanical bond. Cleaning techniques include scrubbing, wire brushing, sanding, chipping, hole filling, torching, solvent cleaning, etc.

2. Primers - can contain rust-inhibitive pigments such as zinc chromate and zinc dust; short drying time paints can expedite field application of top coat.

3. Top coats - vinyl and epoxy paints are commonly used for corrosion applications; many other varieties are also available.

7.8 INFORMATION ON TREATMENT CHEMICALS

7.8.1 General

This section details information on various chemicals which can be used to treat the hazardous spilled materials. Many of the chemicals recommended for use are in themselves very hazardous and must be handled with caution. Two subsections are included. The first deals with the various calculations necessary when chemicals are being handled. The steps include scaleups from bench testing values to ordering the necessary amounts of chemicals to diluting the concentrated chemicals to feed concentrations. The calculations are outlined in this portion of the manual. The second subsection includes additional information on each of the specific chemicals. The information included is as specific as possible but the manufacturer or supplier should be requested to send additional detailed information with the shipped material.

7.8.2 Calculations for Chemical Ordering and Mixing

7.8.2.1 General - The following calculations are designed to allow ordering and mixing of chemicals for the treatment processes. These calculations yield the minimum amounts to order. It is suggested that a 25% excess over the calculated value be ordered to prevent chemical shortages from varying waste quality and chemical spillage, etc. Frequently, unused and unopened containers of chemicals can be returned to the supplier. Chemicals should be ordered as soon as possible to insure arrival on site when the treatment facilities are completed.

7.8.2.2 Conversion of bench scale results to mg/ml - When conducting bench scale tests it is necessary to express the optimum chemical dosage as a weight to volume ratio so that the results can be applied to ordering and mixing chemicals.

Solution:
$$\frac{(\text{Bench test chemical conc. mg/ml}) \times (\text{mls added})}{\text{mls of sample treated}} = \frac{\text{mg bench test chemical}}{\text{ml of sample}}$$

Example: What is the mg of NaOH required per ml of sample for the following test results?

Volume of sample tested: 500 ml
Amount of NaOH added: 25 ml

7.8.2 Mixing chemical to desired strength - After receiving the treatment chemicals it usually is necessary to dilute them to an acceptable concentration for addition.

Solution: If chemical is in the dry form its weight will be known. If it comes as a liquid it can be converted to a weight as follows:

Metric: kg of chemical = l of chemical x density (g/l) x 10^{+3}

English: lbs of chemical = (gallons of chemical) (8.34) (Specific gravity of chemical)

Knowing the desired chemical feed concentration the gallons of water needed per pound of chemical can be determined as follows:

$$\frac{\text{gallons of water needed}}{\text{lb of chemical}} = \frac{\text{\% purity}}{\text{\% feed concentration}}$$

Example: Determine the amount of water needed to mix 20 pounds of NaOH into a 5% solution.

$$\frac{\text{gallons of water needed}}{\text{lb of chemical}} = \frac{(94)+}{5 \times 8.34} = 2.25$$

Total amount of water needed = $\frac{(2.25 \text{ gallons})}{\text{lb}}$ (20 lb) =

45 gallons.

gal. x 3.785 = l
lb x .454 = kg

Solution: If a known amount of dilution water is to be used and the desired feed concentration is known, the amount of chemical to be added can be calculated as follows:

$$\frac{\text{lbs of chemical}}{\text{gallon of water}} = \frac{\text{\% feed concentration} \times 8.34}{(\text{\% purity})}$$

Example: Determine the amount of NaOH at 94% purity needed to mix 100 gallons of a 5% NaOH solution.

$$\frac{\text{lbs of chemical}}{\text{gallon of water}} = \frac{5 \times 8.34}{(94)} = 0.44$$

Total pounds required = (0.44 $\frac{\text{lbs}}{\text{gal.}}$) (100 gal.) = 44.4lbs.

gal. x 3.785 = l
lb. x .454 = kg

7.8.2.5 Ordering liquid chemicals - The purity of certain treatment chemicals is often expressed in degrees baume (Be'). By asking the supplier or referring to a chemical handbook the concentration of the chemical itself can be determined. The normality of the solution should also be known. Listed below are some of the concentrations of chemicals used in treatment.

Chemical	% by weight	Density $D^{20^{\circ}}_{40}$	Baume' degrees	Approximate normality
Acetic acid	96	1.06	8	17
Acetic acid	99-100	1.06	8	18
Hydrochloric acid	36	1.18	22	12
Sulfuric acid	95-97	1.84	66	36

If the results from bench scale tests are reported in mls needed per ml of liquid to be treated, it is possible to calculate the amount of chemical needed as follows:

Solution: Gallons of chemical required =

$$\frac{(\text{mls used})\ (\text{Normally used in lab tests})}{(\text{mls of sample})\ (\text{Normality of chemical ordered})} \times (\text{Gallons to be treated})$$

Example: How much 66° Baume' 36N sulfuric acid is required to treat 1,000,000 gallons if bench scale tests using 2N sulfuric showed that 25 ml were needed for each 500 ml to be treated?

$$\text{Gallons of chemical required} = \frac{(25)}{(500)}\frac{(2N)}{(36N)}(1{,}000{,}000) = 2778 \text{ gal.}$$

gal. x 3.785 = l

If the chemical ordered is based on bench scale tests expressed in mg/l the amount of chemical needed can be determined.

Solution: Knowing the % by weight and the density of the solution, the concentration of the chemical itself can be calculated as follows:

Concentration of chemical = in lb/gallon

$$(\text{Density of solution} \times .0834 \times \%\ \text{by weight of solution})$$

The number of pounds required is simply determined as follows:

Concentration of NaOH test solution: 100 mg/ml

$$\frac{(100\ \text{mg/ml NaOH}) \times (25\ \text{ml})}{500\ \text{ml sample}} = \frac{2500\ \text{mg/ml}}{500} = 5\ \text{mg/ml} \quad \text{NaOH}$$

7.8.2.3 Calculating the total amount of chemical to order - Using the previous example, the total of amount of chemical required can be determined:

Solution: $$\text{kg needed} = \frac{(\text{liters to treat})\ (\text{mg/ml dosage})}{\%\ \text{purity of chemical}\ 0.00834}$$

$$\text{lbs. needed} = \frac{(\text{gallons to treat})\ (\text{mg/ml dosage}) \times 0.834}{\%\ \text{purity of chemical}}$$

Example: How much 94% pure NaOH is needed to treat a spill of 100,000 gallons?

NaOH dosage = 5 mg/ml
gallons to treat = 100,000
NaOH purity = 94%

The following metric conversions are appropriate:

gal. x 3.785 = l
lb x 0.454 = kg

$$\text{lbs needed} = \frac{(100{,}000) \times (5) \times 0.834}{94} = 4436\ \text{lbs}$$

If coagulants are used in the bench tests and the desired dosages are given in mg/l the pounds required can be determined.

Solution: $$\text{lbs needed} = \frac{(\text{gallons to be treated})\ (\text{mg/l coagulant})\ (8.34)\ {*}\text{MWR}{*}}{\text{purity} \times 10{,}000}$$

*MWR is the Molecular Weight Ratio and represents the molecular weight of the chemical ordered divided by the molecular weight of the coagulant itself.

Example: How much $Ca(OH)_2$ is needed to treat 1,000,000 gallons based upon a required CaO coagulant dosage of 100 mg/ℓ?

Coagulant dosage = 100 mg/ℓ as CaO
Chemical ordered = $Ca(OH)_2$
% purity = 98
Gallons to treat = 1,000,000
MW of CaO = 56
MW of $Ca(OH)_2$ = 74

$$\text{lbs needed} = \frac{(1{,}000{,}000)(100)(8.34)}{98 \times 10000} \times \frac{74}{56} = 1124\ \text{lbs}$$

$$\text{lbs required} = \frac{(\text{gallons to be treated})\ (8.34)\ (\text{mg/l})}{1{,}000{,}000}$$

lb x .454 = kg

The number of gallons required is calculated as follows:

Number of gallons = (lbs required) (concentration of chemical in lb/gallon)

gal. x 3.785 = 1

Example: How much $FeCl_3$ is required to treat 100,000 gallons if bench scale tests showed that 50 mg/l of $FeCl_3$ is the needed dosage and with a density of 1.430 and is 40% $FeCl_3$ by weight:

Concentration of chemical = (1.430)(0.0834)(40) = 4.77 lb/gal. lb/gal.

$$\text{lbs required} = \frac{(100{,}000)(8.34)(50)}{1{,}000{,}000} = 41.7 \text{ lb}$$

Number of gallons = (41.6)/(4.77) = 8.74 gal.

7.8.2.6 Diluting liquid chemicals - When diluting liquids such as acetic acid, sulfuric acid or hydrochloric acid for feeding to the treatment system, concentrations ¼ to ½ of the original concentrations are usually used. Since the reaction itself will be monitored (e.g. pH meters) a precise feed concentration is not necessary, therefore a volume to volume dilution will be sufficient.

Solution: To determine the amount of dilution water necessary to reduce the original concentration, the following formula can be used.

$$\text{Amount of water to add} = \frac{(\text{Original \% concentration}) \times (\text{Original amount of water})}{\text{Desired concentration \%}} - (\text{Original amount of water})$$

Example: Determine the amount of water needed to dilute 500 gallons of 93% pure acid to 33%.

$$\text{Amount of water to be added} = \left(\frac{93}{33}\right)(500\text{gals}) - 500\text{gals} = 910\text{gal.}$$

7.8.3 Chemical Data Sheets

The following chemical data sheets are provided as guidelines for using treatment chemicals. Approximate prices are given for estimating purposes, however, these vary with the purity and quantity of the chemical ordered.

The safety precautions listed are minimal. More specific information should be obtained from the manufacturer prior to receiving shipment of chemicals. It is stressed that many of the treatment chemicals are hazardous themselves and must be treated as such. All operators handling chemicals should wear goggles and in most cases chemically resistant aprons and gloves should be used. All chemicals on site should be stored in an isolated area so that unauthorized personnel will not come in contact with them. The handling of chemicals on site must eliminate compounding the hazard that already exists.

Other information also included on the data sheets regards recommended bench testing and feed concentrations for the chemical. Special mixing methods are listed as an aid for those handling the chemical. The cautions reiterate some of the specific problems or hazard potentials. Finally the materials of construction which are acceptable for using the chemical are listed. These are general guidelines since the actual corrosiveness of the solution cannot be estimated and the equipment will only be used on a short term basis so a small rate of corrosion can be tolerated.

Chemical name: Acetic acid CH_3COOH Synonyms:

Alternate chemicals: Very dilute HCl/vinegar (not desirable).

Common package sizes: 450 lb drums.

Approximate costs: $28.00/100 lb.

Purities (from manufacturer) and bulk density: 99.5% (glacial acetic)

Bench test concentrations: up to 100%.

End point determinations: pH meter.

Personal safety: Vapors are irritating to eyes, nose and throat/move victim to fresh air. Compound will burn skin and eyes. Harmful or fatal if swallowed. Remove contaminated clothing and shoes. Flush with plenty of water. If swallowed, give water or milk. DO NOT induce vomiting. Avoid contact with liquid or vapor.

Special mixing methods: Acid to water.

Cautions: Gives off heat upon mixing with water/always add acid to water or a danger of explosion exists.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic
Pumps & Fittings:	

lbx.454 = kg

Figure 76. Data sheet on Acetic acid.

Chemical name: Aluminum sulfate (Alum) $Al_2 (SO_4)_3 \cdot 18 H_2O$

Synonyms: Alum
Filter Alum
Sulfate of Alumina

Alternate chemicals: Ferric chloride or ferric sulfate.

Common package sizes: 100 lb bags 250/350 lb barr. bulk C/L

Approximate costs: $5.90/100 lbs.

Purities (from manufacturer) and bulk density: 17% Al_2O_3 (aluminum oxide) 60-75#/$_{ft}3$

Bench test concentrations: 100 mg/ml as $Al_2(SO_4)_3 \cdot 18 H_2O$.

Feed concentrations: 3%

End point determinations: Floc is substantial.

Personal safety: Hazardous if ingested or inhaled - avoid breathing dust. May form acid solution capable of causing burns. In case of contact with skin or eyes remove clothing and shoes and flush with plenty of water.

Special mixing methods: Is slow to dissolve so mixing is critical.

Cautions: Granular solid is superior/corrosive and acidic once in solution. Be careful not to breathe dust.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic	
Pumps & Fittings:	Dry - iron/steel/concrete	Wet - lead/rubber/Duriron/asphalt/cypross/316-st. steel

lbx.454 = kg

Figure 77. Data sheet on Aluminum sulfate.

Chemical name: Calcium Chloride $CaCl_2$ Synonyms:

Alternate chemicals: None

Common package sizes: Flakes: 100 lb bags Pellets: 80 lb lots

Approximate costs: \$7.25 - 11.35/100# \$8.65 - 13.50/100#

Purities (from manufacturer): 77-94% as $CaCl_2$.

Bench test concentrations: 100 mg/ml

Feed concentrations: 10-20%.

End point determinations: When Ca ppt is no longer formed.

Personal safety: Do not inhale or ingest. Remove victim to fresh air. Remove contaminated clothing and shoes and flush with plenty of water.

Special mixing methods: Dissolves easily/do not breath dust/heat may be liberated when dissolved.

Cautions: is Somewhat corrosive/flakes dissolve quickly.

Materials for handling:

Tanks: Process - any
Chemical - concrete/plastic/other

Pumps & Fittings:	Conc: Rubber	Dilute: Steel (up to 50% cast iron)

lbx.454 = kg

Figure 78. Data sheet on Calcium chloride.

Chemical name: Calcium Hydroxide-
slaked lime - $Ca(OH)_2$

Synonyms: Chemical lime
Lime
Slaked lime
Hydrated lime

Alternate chemicals: Calcium oxide.

Common packages sizes: 50# bag.

Approximate costs: $2.04/100#.

Purities (from manufacturer) 94-95% 35-50 lb/ft^3.
and bulk density:
Bench test concentrations: 100 mg/ml as CaO.

Feed concentrations: Dry or 10% solution (0.93 lb/gal.).

End point determinations: pH and floc production.

Personal safety: Dust irritating to nose and throat - move to fresh air. Will burn skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected area with plenty of water. If swallowed and victim is conscious have victim drink water or milk. DO NOT induce vomiting.

Special mixing methods: Lime will form a slurry which requires mixing throughout the feeding period. Slaking of $Ca(OH)_2$ requires 30-60 min to complete. Use velocities of 5-7 fps to feed.

Cautions: Heats and expands on reaction with water. Adsorbs H_2O and CO_2 from air to form $CaCO_3$. Do not breathe dust.

Materials for handling:

Tanks:	Process - any Chemical - plastic/other
Pumps & Fittings:	Rubber hose/iron/steel/asphalt/concrete No lead

lbx.454 = kg
gal. x 3.785 = l

Figure 79. Data sheet on Calcium hydroxide.

Chemical name: Calcium oxide (lime)
CaO

Synonyms: Unslaked lime
Quick lime
Burnt lime

Alternate chemicals: Calcium hydroxide.

Common package sizes: 80 lb bags.

Approximate costs: $2.28/100 lb.

Purities (from manufacturer) 94-95% 55-70 lb/ft^3
and bulk density:
Bench test concentrations: 100 mg/ml as CaO.

Feed concentrations: Slake and dilute to less than 10% - Each pound of CaO will slake to 1.16-1.32 lb of $Ca(OH)_2$ and 2-17% grit.

End point determinations: pH and floc formation.

Personal safety: Dust irritating to nose and throat. Move victim to fresh air. Will burn and eyes. Harmful if ingested. Remove contaminated clothing and shoes. Flush affected area with plenty of water. If swallowed and victim is conscious, have victim drink water or milk. DO NOT induce vomiting.

Special mixing methods: Slaking requires 30-60 minutes with heat evolution and expansion: slurry will require continuous mixing and pumping at 5-7 fps.

Cautions: Basic and adds alkalinity to water/can be corrosive/will increase water temperature. Caution is needed.

Materials for handling:

Tanks: Process - any
Chemical - plastic/other

Pumps & Fittings: Dry - iron/steel/concrete Wet - iron/steel/rubber hose/concrete

lbx.454 = kg

Figure 80. Data sheet on Calcium oxide.

Chemical name: Ferric chloride
$FeCl_3$

Synonyms: Ferric chloride
Chloride of iron
Crystal ferric chloride
Anhydrous ferric chloride
Ferric floc

Alternate chemicals: Alum/ferric sulfate
Ferrous sulfate

Common package sizes: 55 gal. drum-42° baume' 175 and 610 lb drums

Approximate costs: $9.65/100 lb (liquid)

Purities (from manufacturer) and bulk density: Liquid - 39% - 11.2-12.4#/ft^3
Solid-hepta hydrate 60% $FeCl_3$-60-64#/ft 3

Bench test concentrations: 100 mg/ml $FeCl_3$.

Feed concentrations: <45% generally, 15% will control hydrolysis.

End point determinations: pH and floc formation.

Personal safety: Forms corrosive acid solution in water. Releases toxic chlorides when heated to decomposition. Mild irritant. Slight ingestion hazard. Remove contaminated clothing and shoes and flush with plenty of water.

Special mixing methods: Dissolves very easily and should be fed in solution.

Cautions: Is a hygroscopic solid and forms an acidic and corrosive liquid/protect from light.

Materials for handling:

Tasks:	Process - any Chemical - concrete/plastic
Pumps & Fittings:	Rubber/glass/ceramics/plastic

lbx.454 = kg

Figure 81. Data sheet on Ferric chloride.

Chemical name:	Ferrous sulfate $FeSO_4 \cdot 7H_2O$	Synonyms:	Ferriclear Copperas Sugar sulfate Green vitriol

Alternate chemicals: None

Common packages sizes.: 50 and 100 lb bags

Approximate costs: $2.85-3.85/100 lb.

Purities (from manufacturer): 20% Fe (granular), $63\text{-}66\#/ft^3$
and bulk density:

Bench test concentrations: 100 mg/ml (50-200 mg/ml)

Feed concentrations: 240 mg/ml (2 lb/gal.)

End point determinations: Add to floc or dosage

Personal safety: Hazardous if inhaled or ingested. A mild irritant to skin and eyes. Remove contaminated clothing and shoes - Flush with plenty of water. If swallowed and victim is conscious, have victim drink water or milk and have victim induce vomiting. If swallowed and victim is unconscious or having convulsions, call for help and to nothing except keep victim warm.

Special mixing methods: Mix for at least 5 minutes. Granules dissolve best.

Cautions: Solution formed is quite acidic.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic
Pumps & Fittings:	Stainless steel 316 Rubber/lead/ceramic/Duriron

lbx.454 = kg

Figure 82. Data sheet on Ferrous sulfate.

Chemical name: Hydrochloric acid   Synonyms: Muriatic acid
HCl

Alternate chemicals: Sulfuric acid (sometimes).

Common package sizes: 65, 145, 700 lb drums.

Approximate costs: $6.85-$9.00/100 lb.

Purities (from manufacturer): 22° Baume'.

Bench test concentrations: 100 mg/ml HCl

Feed concentrations: 36% max-use of 18% dilute HCl is safer.

End point determinations: pH

Personal safety: Vapor and liquid irritating to eyes, nose and throat. Will cause difficult breathing. Move victim to fresh air. Liquid will burn eyes and skin. Remove clothing and shoes. Flush affected areas with plenty of water. If swallowed and victim is conscious, have victim drink water. DO NOT induce vomiting.

Special mixing methods: Evolves heat and fumes when mixed with water - add acid to water in all situations.

Cautions: Beware of fumes from the system, wear goggles, rubber gloves, apron. Severely burns skin. Always add acid to water to avoid danger of explosion.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic
Pumps & Fittings:	Plastic/rubber/porcelain

lb.454 = kg

Figure 83. Data sheet on Hydrochloric acid.

Chemical name: Polyelectrolytes   Synonyms: Polymers

Alternate chemicals: $FeCl_3$ or $Al_2SO_4 . 18\ H_2O$

Common package sizes: 50 lb bags or 55 gal. drums

Approximate costs: $2.00/# (need only small amounts so should purchase in pound lots).

Purities (from manufacturer)   99%   40-50#/ft^3
and bulk density:

Bench test concentrations: 1 mg/ml (0.5-1 mg/ml)

Feed concentrations: 0.5-1%

End point determinations: Floc formation

Personal safety: Do not breathe fumes or touch powder. Flush with plenty of water.

Special mixing methods: Difficult to mix/add to rapidly swirling water/ mix at least 1 hour prior to use/mix and use the same day.

Cautions: Viscous fluids requiring mixing and high pumping rates.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic/other
Pumps & Fittings:	Do not use aluminum or galvanized equipment. Use: plastic/stainless steel/cast iron

lbx.454 = kg
gal.x3.785 = l

Figure 84. Data sheet on Polyelectrolytes.

Chemical name: Potassium Permanganate Synonyms:
$KMnO_4$

Alternate chemicals: None

Common package sizes: 50, 100, 150 lb drums

Approximate costs: $52-69/100 lb

Purities (from manufacturer): 97% minimum

Bench test concentrations: 10-100 mg/ml as $KMnO_4$

Feed concentrations: 10%

End point determinations: Oxygen demand

Personal safety: Highly toxic if inhaled or ingested. High concentrations are cuastic. A strong irritant. Remove clothing and shoes and flush with water. If swallowed and victim is conscious have victim drink water or milk and have victim induce vomiting. If swallowed and victim is unconscious or having convulsions, call for help and keep victim warm.

Special mixing methods: Will dissolve better in cold water: (an oxidizing agent).

Cautions: Easily reduced by natural reducers (e.g., organics, sulfite, nitrite, etc).

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic (low conc.)
Pumps & Fittings:	Cast iron, plastic/stainless steel/steel

lbx.454 = kg

Figure 85. Data sheet on Potassium Permanganate.

Chemical name: Sodium Bicarbonate $NaHCO_3$ **Synonyms:** Baking soda

Alternate chemicals: Sodium carbonate

Common package sizes: 100 lb bags

Approximate costs: $6.95/100 lb

Purities (from manufacturer) and bulk density: 99.6% 59-62#/ft 3

Bench test concentrations: 100 mg/ml as $NaHCO_3$.

Feed concentrations: 60 mg/ml (0.5 lb/gal.)

End point determinations: pH

Personal safety: Do not ingest or inhale. In case of contact with eyes or skin, flush with plenty of water.

Special mixing methods: None - dissolves quite easily.

Cautions: Slightly alkaline - 1% solution - pH 8.2 alkalinity increases at higher temperatures.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic/other
Pumps & Fittings:	Iron, steel, rubber, stainless steel

lbx.454 = kg
ft3x.028 = m

Figure 86. Data sheet on Sodium bicarbonate

Chemical name: Sodium bisulfite $NaHSO_3$ Synonyms:

Alternate chemicals: Sodium metabisulfite or Sodium sulfite

Common package sizes: 100 lb bags

Approximate costs: $18.05/100 lb.

Purities (from manufacturer) and bulk density: 99% as $Na_2S_2O_5$ 70-80 #/ft 3 65.5% SO_2

Bench test concentrations: 50 mg/ml as $NaHSO_3$

Feed concentrations: 60 mg/ml

End point determinations: Large ORP change.

Personal safety: Slowly release toxic gas if exposed to fire, water or acids to produce a highly corrosive hazard. Prevent inhalation and ingestion of solid and liquid. If inhaled move victim to fresh air, irritating to eyes nose, and throat. In case of contact, remove clothes and shoes and flush with plenty of water. If swallowed, drink water or milk.

Special mixing methods: None

Cautions: Acidic solution - $NaHSO_3$/eventually oxidized to sulfate.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic/other
Pumps & Fittings:	Lead, rubber, glass, ceramic, chrome, nickel, stainless steel.

lbx.454 = kg
ft^3x.028 = m^3

Figure 87. Data sheet on Sodium bisulfite.

Chemical name: Sodium carbonate (soda ash) Na_2CO_3

Synonyms: Soda ash
Soda ash - 58%
Sol. soda

Alternate chemicals: Sodium bicarbonate

Common package sizes: 100 lb bags

Approximate costs: $3.70/100 lb

Purities (from manufacturer) and bulk density: 99% Na_2CO_3 } 30-65#/ft^3
58% Na_2O (sodium oxide)

Bench test concentrations: 100 mg/ml as Na_2CO_3

Feed concentrations: 120 mg/ml

End point determinations: pH

Personal safety: Avoid inhaling or ingesting. Move victim to fresh air. Very caustic, will cause burns to skin and eyes. Remove clothing and shoes. Flush affected area with plenty of water.

Special mixing methods: Mix at least 10-20 min/#/gal. of added Na_2CO_3/ mixes with large evolution of heat.

Cautions: Alkaline solution (ph 11.6) hygroscopic solid.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic/other
Pumps & Fittings:	Iron, steel, rubber hose

lbx.454 = kg
ft3x.028 = m3

Figure 88. Data sheet on Sodium carbonate.

Chemical name: Sodium Hydroxide (caustic) NaOH Synonyms: Caustic soda
Caustic soda lye

Alternate chemicals: Potassium hydroxide
Ammonium hydroxide (undesirable)

Common package sizes: 650 lb drum - 50% solution/400 # flake

Approximate costs: \$10.-12/100# (liquid) $\frac{\$21.60\text{-}27.55}{100}$ (flake)

Purities (from manufacturer) and bulk density: 50% liquid 76% flake and bulk density

Bench test concentrations: 100 mg/ml.

Feed concentrations: 12-50%

End point determinations: pH

Personal safety: Very caustic. Do not handle with bare hands, do not ingest or inhale dust. Move victim to fresh air. In case of contact remove contaminated clothing and shoes and flush with plenty of water. If swallowed and victim is conscious, have victim drink water or milk. DO NOT induce vomiting.

Special mixing methods: Diliquescent, causes poison - be careful not to add solid too fast, solution feed is absolutely necessary/large heat evolution when mixed.

Cautions: Very dangerous to handle - alkaline to pH 12.9 - at 1% solution/ wear goggles, rubber gloves, aprons (rapidly adsorbs water and CO_2 from air.

Materials for handling:

Tanks:	Process - any
Pumps & Fittings:	Cast iron, rubber, steel

lbx.454 = kg

Figure 89. Data sheet on Sodium hydroxide.

Chemical name: Sodium Hypochlorite
NaClO

Synonyms:
Chlorox
Liquid bleach
Javille water
Chlorine bleach

Alternate chemicals: Calcium hypochlorite

Common package sizes: 5, 15, 50, 1,000, 4,500, gal. (12.5%)

Approximate costs: \$0.36 - 0.48/100 lb

Purities (from manufacturer): 12.5% (available chlorine) 13.1 % Na & Cl

Bench test concentrations: 0.5-5% chlorine

Feed concentrations: 5.0%

End point determinations: Chlorine residual

Personal safety: Vapor or liquid harmful or fatal if inhaled or ingested. Can cause burns upon contact with eyes or skin. In case of contamination remove shoes and clothing and flush with water. If swallowed and victim is conscious, have victim drink water or milk and have victim induce vomiting. If swallowed and victim is unconscious or having convulsions, call for help and keep victim warm.

Special mixing methods: Is a very corrosive material.

Cautions: Avoid breathing vapors/do not mix with ammonia.

Materials for handling:

Tanks: Process - any
Chemical - concrete/plastic/other

Pumps & Fittings: Rubber, plastics, glass, ceramics

lbx.454 = kg

Figure 90. Data sheet on Sodium Hypochlorite.

Chemical name: Sodium Sulfate Synonyms: Glaubers salt
Na_2SO_4

Alternate chemicals: Potassium sulfate

Common package sizes: 100 lb bags

Approximate costs: $6.50/100 lb

Purities (from manufacturer): 99.5%

Bench test concentrations: 100 mg/ml

Feed concentrations: 10-20%

End point determinations: Sulfate test

Personal safety: Do not inhale or ingest. Can be irritating to eyes or skin. Remove clothing and shoes and flush with water.

Special mixing methods: Neutral solution pH 6-7 when mixed.

Cautions:

Materials for handling:

Tanks: Process - any
Chemical - any

Pumps & Fittings: Stainless steel, rubber, plastic, cast iron

lbx.454 = kg

Figure 91. Data sheet on Sodium sulfate.

Chemical name: Sodium sulfide Synonyms:
Na_2S or $Na_2S.9H_2O$
(Sodium sulfide enneahydrate)

Alternate chemicals: Ammonium sulfide

Common package sizes: 100 lb drum

Approximate costs: \$26.50/100 lb

Purities (from manufacturer): 60-62%

Bench test concentrations: 50

Feed concentrations: 10%

End point determinations: Zinc acetate paper/removal of metal ion.

Personal safety: Yields sulfur dioxide and hydrogen sulfide which is extremely flamable and toxic on contact with acids or fire. Irritant-remove victims clothing and shoes and flush with water. If swallowed and victim is conscious have victim drink water or milk. Dust irritating to nose, eyes and throat. Move victim to fresh air.

Special mixing methods: Mix slowly checkingpH add $Ca(OH)_2$ or NaOH if pH drops below 7/however most solutions are alkaline: should be used immediately.

Cautions: Caution to avoid evolution of toxic H_2S which occurs at low pH values. Do not expose solid to air without the use of a self contained breathing apparatus.

Materials for handling:

Tanks:	Process - any Chemical - any
Pumps & Fittings:	Cast iron

lbx.454 = kg

Figure 92. Data sheet on Sodium Sulfide.

Chemical name: Sulfuric acid
H_2SO_4

Synonyms: Oil of Vitriol
Battery acid
Fertilizer acid

Alternate chemicals: Hydrochloric acid

Common package sizes: 5 gal. carboys/ 55, 110 gal. drums

Approximate costs: \$8.40 - 15.35/100#

Purities (from manufacturer): 66° Baume'

Bench test concentrations: 50 mg/ml - H_2SO_4 (1N)

Feed concentrations: up to 96% to use diluted at 25%.

End point determinations: pH.

Personal safety: Vapors are irritating to eyes, nose and throat. Move victim to fresh air. Compound will burn skin and eyes. Harmful or fatal if swallowed. Remove contaminated clothing and shoes and flush with plenty of water. If swallowed and victim is conscious, have victim drink water or milk. DO NOT induce vomiting.

Special mixing methods: Acid to water - ONLY - has high affinity for water - add very slowly to reduce heat evolution.

Cautions: Corrosive and hygroscopic/very acidic pH 1.2, need goggles, rubber gloves, aprons/burns skin. Heat evolved upon mixing/always add acid to water to avoid danger of explosion.

Materials for handling:

Tanks:	Process - any Chemical - concrete/plastic
Pumps & Fittings:	Conc. steel/iron Dilute/lead, porcelain, rubber, glass

lbx.454 = kg

Figure 93. Data sheet on Sulfuric acid.

7.9 SUPPLIERS INFORMATION

7.9.1 General

This section includes information regarding sources of supply for the various media and chemicals needed. The amounts of materials needed have been calculated as indicated in other sections, but this amount should be verified with the manufacturer. It is critical that all of these materials be ordered immediately since the shipping time may exceed 24 hours. It may be necessary to make special arrangements to allow shipment to the spill site immediately.

The phone numbers of suppliers are included where possible. To obtain treatment chemicals, the OSC should check with local suppliers, then complete the table in this subsection and provide phone numbers to handle all situations. Possible local sources are also listed.

7.9.2 Filter Supplies

Media	Source	Yellow Pages Heading
Coarse gravel:	Local sand and gravel dealer	Sand and Gravel
Filter sand:	Local water treatment plant	
	Sandblast supplier (to get sandblast sand)	Sandblasting Equipment and Supplies
Filter Coal: (crushed anthracite)	Local water treatment plant	

Suppliers:

1. Carbonite Filter Company
   P. O. Box 1
   Delane, PA 18220
   717/467-3350

2. Palmer Filter Equipment Co.
   P. O. Box 50
   Fairview, PA 16415
   814/474-5555

7.9.3 Ion Exchange Media

Ion Exchange Media must be ordered from the following suppliers and information transferred to these dealers regarding the specific wastewater to treat:

1. Bio-Red Laboratories
   32nd and Griffin Ave.
   Richmond, CA 94804
   415/234-4130

2. Dow Chemical Co.
   2030 Dow Center
   Midland, MI 48640
   517/636-1000

3. E.I. du Pont Nemours and Co. - Plastics Division
   1007 Market Street
   Wilmington, DE 19898
   302/774-2421

4. Ionac Chemical Co. - Division Sybron Corp.
   P. O. Box 66
   Birmingham Road
   Birmingham, NJ 08011
   609/894-8211

5. Mallinckrodt Chemical Works
   P. O. Box 5439
   St. Louis, MO 63160
   314/231-8980

6. Rohm and Haas Co.
   Independent Mall West
   Philadelphia, PA 19105
   215/592-3170

7. Union Carbide - Linde Division
   270 Park Avenue
   New York, NY 10017
   212/351-2345

7.9.4 Granular Activated Carbon

Manufacturer	Order Points	Shipping Points	Method of Shipment
Calgon Corp.	Calgon Adsorption Systems Box 1346 Pittsburgh, PA 15230 412/923-2345	Cattettsburg, KY	Bags, 60 lb Bulk Truck, 20-40,000 lb Rail, 80,000 lb

Manufacturer	Order Points	Shipping Points	Method of Shipment
	7405 Page Ave. St. Louis, MO 63133 314/683-3200	Houston (Bayport), TX	Bags, 60 lb Bulk Truck, 20-40,000 lb
	4800 W. 34th St., Suite B-8 Houston, TX 77018 713/682-1301	Seattle, WA	Bags, 60 lb
		City of Industry, CA	Bags, 60 lb
Witco Chemical Corp.	277 Park Ave. New York, NY 10017 212/644-6435	Petrolia, PA	Bags or bulk
Westvaco	Eastern States		
	J.F. Henry Chemical Co. East Rutherford, NJ	Same	--
	Westvaco Carbon Sales Dept. Covington, VA 24426	Same	Bags or bulk
	Herbert Chemical Co. Cincinnati, OH	Same	--
	Western States		
	Van Waters & Rogers San Francisco, Los Angeles, Portland, Kent, Denver	Same	--
ICI America, Inc. Atlas Chemicals Div.	Chicago, IL 312/775-4900 Dallas, TX 214/330-9580 New York, NY 212/688-1430 San Francisco, CA 415/341-5891 Wilmington, DE 302/658-9311 Los Angeles, CA 213/872-0127	Marshall, TX	Bags or bulk

7.9.5 Treatment Chemicals

Local Sources -

Chemical	Use	Possible Local Source
Acetic Acid	Neutralization pH control	Grocery Store/Vinegar Industry/ Industrial Supplier
Aluminum Sulfate (Alum)	Precipitant/ Coagulant	Water Treatment Plant Industry/ Industrial Supplier
Calcium Chloride	Precipitant/ Coagulant	Industry/Industrial Supplier
Calcium Hydroxide (Slaked Lime)	Neutralization/ Precipitant	Agricultural Supply/ Water and Wastewater Treatment Plant/ Industry/Industrial Supplier
Calcium Oxide (Lime)	Neutralization/ Precipitation	Agricultural Supply/Water and Wastewater Treatment Plant/ Industry/Industrial Supplier
Ferric Chloride	Precipitant/ Coagulant	Wastewater Treatment Plant/ Industry/Industrial Supplier
Ferrous Sulfate	Reducing Agent/ Precipitant/ Coagulant	Wastewater Treatment Plant/ Industry (pickle liquor)/ Industrial Supplier
Hydrochloric Acid (Muriatic Acid)	Neutralization/ pH control	Industry/Industrial Supplier
Polyelectrolytes	Coagulant ion	Sewage Treatment Plant/Water Treatment Plant
Potassium Permanganate	Oxidizing Agent	Industry/Industrial Supplier
Sodium Bi-carbonate	Neutralization/ precipitation	Grocery Store/as baking soda Industry/Industrial Supplier
Sodium Bisulfate	Precipitant	Industry/Industrial Supplier
Sodium Bisulfite	Reducing Agent	Industry/Industrial Supplier
Sodium Carbonate (Soda Ash)	Precipitation	Water Treatment Plant/Industry/ Industrial Supplier

Chemical	Use	Possible Local Source
Sodium Hydroxide (Caustic Soda)	Neutralization/ Precipitant	Industry/Industrial Supplier
Sodium Hypochlorite	Oxidizing Agent	As Bleach/Grocery Store/ Industry/Industrial Supplier
Sodium Sulfate	Precipitant	Industry/Industrial Supplier
Sodium Sulfide	Reducing Agent/ Precipitant	Industry/Industrial Supplier
Sulfuric Acid	Neutralization/ pH control	Industry/Industrial Supplier

When chemicals are not readily available locally, they must be ordered from a manufacturer. The OSC should prepare a list of chemical sources which includes a 24 hour phone number, the location of the regional warehouse, and the availability of chemicals. The following format is presented to aid the OSC in collecting sufficient information. The chart should be completed for each of the 19 treatment chemicals.

7.10 CALCULATION AIDES AND DEFINITIONS

The following tables are designed to clarify the information which is presented in the preceding subsections. It also eliminates the requirement for definitions throughout the text by placing them in one general listing. The following three subjects are covered:

Unit Abbreviations	- Gives the meaning of the abbreviation, the definition and unit type
Conversion Factors	- Common English to Metric conversion factors are given as are interconversion between various weights and measures
Glossary	- Terms used in the text are defined regarding the context in which they are used in this report

Chemical	Supplier and Location	Office Phone	24 Hour Phone	Amount Immed. Available	Time Needed to Order Larger Amount

Figure 94. Format for chemical suppliers information

Unit Abbreviations

Symbol	Definitions	Dimensions	Type of Unit
cm	centimeter	L	length
fpm	feet per minute	L/T	velocity length/time
ft	feet	L	length
ft^2	square feet	L^2	generally surface area
gal	gallons	L^3	volume
gpd	gallons per day	L^3/T	volume/time
gpm	gallons per minute	L^3/T	volume/time
gpm/ft^2	gallons per minute per square ft	$\frac{L^3/T}{L^2}$	loading rate
Hp	process height	L	length
hr	hour	T	time
in	inch	L	length
in. Hg	inches of mercury	L	pressure
l	liter	L^3	volume
lb	pounds	W	weight
m	meter	L	length
min	minute	T	time
mg	milligram (1/1000th gram)	W	weight
ml	milliliter (1/1000th of a liter)	L^3	volume
m^3	cubic meters	L^3	volume
N	normality	-	concentration
n_p	number of process tanks	-	-
n_s	number of sludge tanks		
POI	position of the interface	L	length
Qp	process flow rate	L^3/T	volume/time
sec	second	T	time
Sp.g	specific gravity	-	-

Symbol	Definitions	Dimensions	Type of Unit
t_d	detention time for reaction	T	time
t_{ds}	time to desludge	T	time
t_{draw}	time to draw	T	time
t_{fill}	time to fill	T	time
t_T	total detention time	T	time
Vp	process volume	L^3	volume
Vp (eff)	corrected process volume	L^3	volume
#	pounds	W	weight
	pump	-	-
%	percent	-	-
	chemical feed system	-	-

Conversion Factors

English Unit	Multiplier	Metric Unit
acre	0.405	ha
acre-ft	1,233.5	cu m
Btu	0.252	kg-cal
Btu/lb	0.555	kg-cal/kg
bu	35.24	l
bu	0.03524	cu m
cfm	0.028	cu m/min
cfs	1.7	cu m/min
cfs/acre	4.2	cu m/min/ha
cfs/sq mile	0.657	cu m/min/sq km
cu ft	0.028	cu m
cu ft	28.32	l
cu in.	16.39	cu cm
cu yd	0.75	cu m
cu yd/mile	0.475	cu m/km
cu yd/sq mile	0.29	cu m/sq km
$^{\circ}$F	0.555 ($^{\circ}$F-32)	$^{\circ}$C
fathom	1.8	m
ft	0.3048	m
ft-c	10.764	lumen/sq m

gal	0.003785	cu m
gal	3.785	l
gpd/acre	0.00935	cu m/day/ha
gpd/cu yd	5.0	l/day/cu m
gpd/ft	0.0124	cu m/day/m
gpd/sq ft	0.0408	cu m/day/sq m
gpm	0.0631	l/sec
gpm/sq ft	40.7	l/min/sq m
hp	0.7457	kw
in.	2.54	cm
lb	0.454	kg
lb/day/acre	11.2	kg/day/ha
lb/day/acre-ft	3.68	g/day/cu m
lb/1,000 cu ft	16.0	g/cu m
lb/acre/day	0.112	g/day/sq m
lb/day/cu ft	16	kg/day/cu m
lb/day/cu yd	0.6	kg/day/cu m
lb/day/sq ft	4,880	g/day/sq m
lb/ft	1.51	kg/m
lb/mil gal	0.12	g/cu m
mgd	3,785	cu m/day
mgd/acre	9,360	cu m/day/ha
mile	1.61	km
ppb	10^{-3}	mg/l
pcf	16.02	kg/cu m
psf	4.88	kg/sq m
psi	0.0703	kg/sq cm
sq ft	0.0929	sq m
sq ft/cu ft	3.29	sq m/cu m
sq in.	6.452	sq cm
sq miles	2.590	sq km
tons (short)	907	kg
tons (short)	0.907	metric tons

Taken From: The Journal of the Water Pollution Control Federation

Length

Miles	Yards	Feet	Inches	Centimeters
1	1760	5280	--	--
--	1	3	36	91.44
--	--	1	12	30.48
--	--	--	1	2.540

1 m = 100 cm = 3.281 ft = 39.37 in.

Area

Square Miles	Acres	Square Feet	Square Inches	Square Centimeters
1	640	--	--	--
--	1	43,560	--	--
--	--	1	144	929.0
--	--	--	1	6.452

1 sq m = 10.76 sq ft

Volume

Cubic Feet	Imperial Gallons	U. S. Gallons	Cubic Inches	Liters
1	6.23	7.481	1728	28.32
--	1	1.2	277.4	4.536
--	--	1	231	3.785
--	--	--	57.75	0.946
--	--	--	61.02	1

1 cu m = 35.31 cu ft - 264.2 gal

1 Imperial (UK) gal weighs 10 lb   1 US gal weighs 8.34 lb

1 cu ft of water weighs 62.43 lb   1 cu m weighs 2283 lb

1 cu m - 10^3 l and weighs 1000 kg

Velocity

Miles per Hour	Feet per Second	Inches per Minute	Centimeters per Second	Kilometers per Hour
1	1.467	1056	--	1.609
--	1	720	30.48	--
--	--	1	0.423	--

Time

Days	Hours	Minutes	Seconds
1	24	1440	86,400
--	1	60	3,600
--	--	1	60

Weight

Tons	Pounds	Grams	Grains	Metric Tons
1	2000	--	--	0.9078
--	1	454	7000	--
--	--	1	15.43	--

1 long ton = 2240 lb

1 ppm = 1 mg/l = 8.34 lb per mg

Discharge

Cubic Feet per Second	Million Gallons Daily	Gallons per Minute
1	0.6463	448.8
1.547	1	694.4

1 in. per hour per acre = 1.008 cfs

1 cu m/sec = 22.83 mgd = 35.32 cfs

Pressure

Pounds per Square Inch	Feet of Water	Inches of Mercury
1	2.307	2.036
0.4335	1	0.8825
0.4912	1.133	1

1 atm = 14.70 psia = 29.92 in. Hg = 33.93 ft water = 76.0 cm Hg

Power

Kilowatts	Horsepower	Foot-Pounds per Second	Kilogram-Meters per Second
1	1.341	737.6	102.0
0.7457	1	550	76.04

Work, Energy, and Heat

Kilowatt-Hours	Horsepower-Hours	British Thermal Units	Calories
1	1.341	3412	8.6×10^5
0.7457	1	2544	6.4×10^5

Temperature

Degree Fahrenheit = 32 + $\frac{9}{5}$ x degrees Centigrade

0	5	10	15	20	25	30	35	40	45	50	55	60	C
32	41	50	59	68	77	86	95	104	113	122	131	140	F

Taken From: Fair, Geyer and Okun
Water and Wastewater Engineering (15)

GLOSSARY OF TERMS

Accessibility - The ease and safety of approaching a site.

Acidic - A solution which has acid properties and contains excess (over neutral) concentration of hydrogen ions.

Activated Carbon Adsorption - A process by which granular activated carbon selectively removes some organics and inorganics by physical surface attraction.

Adsorption Capacity - An indicator of the amount of contaminant a certain type of carbon can remove.

Aeration - The oxidation of contaminants by forcing air through a solution of wastewater.

Alkaline - A basic solution which contains large amounts of hydroxyl ions.

Anion - A negatively charged ion. (Anionic - possessing a negative charge)

Backwash - Forcing water at a high flow rate in tne opposite direction of operational flow to remove particulates that blind the media.

Ballast - A heavy material placed in a container to enhance the stability.

Batch - 1. The volume of fluid equal to the process capacity of a tank.
2. An operation which is not continuous whereby all operations are done on one volume in the same tank.

Bench Testing - Small scale procedures to establish the treatment parameters for a specific wastewater.

Breakthrough - A condition which occurs when a media's capacity for removing a contaminant is exhausted.

Cation - An electron having a positive charge. (Cationic - possessing positive charges)

Chemical Injection - The process of adding a treatment chemical to the wastewater. Specific points of addition and methods are needed.

Chlorination - The oxidation of contaminants by addition of chlorine or other chlorine compounds.

Clarification - The removal of turbidity and solids from a solution through the sedimentation or flotation process.

Coagulation - A physical-chemical process which involves the reduction of surface charges and the formation of complex hydrous oxides.

Desludging - Operation of removing settled material (solids) from the bottom of a sedimentation or precipitation reaction tank by pumping into a separate holding tank.

Detention Time - The length of time a volume of solution is contained in the treatment process. Does not include filling and drawing time in this context.

Diffuser - A mechanical device that allows bubbles of air to be injected into a solution. Various types are available from a small porous stone to a tube of steel covered with porous bags.

Downtime - The time during which process flow is stopped and backwashing, desludging and maintenance operations are performed.

Effective Size - That size of media that 10% by weight is smaller than and 90% by weight is larger than.

Endpoint - The indication of the process completion. The type depends on the test being used.

Equalization Tank - An extra process tank used to balance inconsistant flows and provide an even flow of wastewater to downstream processes.

Fill Time/Draw Time - The amount of time needed to fill (draw) a process tank. Equivalent to the process volume of the tank divided by either the system or pump flow rate.

Filtration - The removal of particulate matter by passing a waste stream through a bed of graded media.

Filtration Rate - The flow of water through a unit of filter surface area [l/min/m^2 or gpm/ft^2].

Fines - The small particles which are present with most coarse media and can cause surface blinding.

Floc - The enlarged particles that are formed after chemical addition and contact. Generally a physiochemical reaction creates a desirable large and distinct floc.

Flocculation - This is the opportunity for particle contact to allow increased size of the particles. It is done at a speed just fast enough to keep the materials in suspension without breaking up the floc.

Flotation - A unit of operation to separate solid or liquid particles from the liquid phase which have a specific gravity less than water.

Freeboard - In a process tank the vertical distance from the fluid level to the top of the tank.

In Situ - Within the system/in this situation referring to treatment within the contaminated water body.

Inorganic Contaminants - Spilled compounds consisting of any element except carbon.

Insoluble - Not capable of being dissolved, generally considered in water.

Ion Exchange - A process in which ions held by electrostatic forces to functional groups on the surface of a solid or exchanged for ions of a different species in solution.

Limiting Factors - Those variables (or variable) which establish a maximum process flow rate through the system.

Mixing - To agitate sufficiently to blend the contents of a tank with the added materials.

Neutralization - The adjustment of pH to approach a value of 7.

Nonionic - Possessing an excess of neither positive or negative charges.

Off Stream Treatment - Treatment of a contaminant by removing the wastewater and treating it in a location adjacent to the waterway.

Organic Contaminants - Spilled materials which are compounds of carbon.

ORP - (Oxidation Reduction Potential) - A measurement of the positive and negative ion concentration. Measured by a platinum electrode on a meter.

Oxidation - The chemical reaction which involves a loss of electrons by the waste species being treated.

Parallel Operation - A mode of operation in which a wastewater is treated by splitting the flow into a group of simultaneous process units.

pH Meter - An electric meter which measures the pH by the use of a calomel electrode. It may require manual temperature compensation.

pH of a Solution - pH is the negative log of the hydrogen ion concentration $(-\log[H^+])$ and is a measure of the intensity of acid or alkaline condition of a solution.

pH Paper - Dyed paper which gives a rough indication of the pH (e.g. H^+ ion concentration) of the solution.

Precipitation - Treatment process in which reagents are added to form insoluble products with the specific pollutants.

Presettler - A process tank used to remove the bulk of solids or sludges that settles rapidly from a water column. It is continuously desludged and used when solids volume is greater than 3% of the flow,as well as in other applications.

Pretreatment - Early removal of certain contaminants to reduce the load on downstream treatment processes.

Process Effluent - The treated fluid exiting a process element.

Process Head Loss - The pressure necessary to overcome the resistance to flow through the process media and media supports.

Process Height - The height to which the tank is filled and it is equal to the total height of the tank minus the freeboard.

Process Influent - The fluid entering a process element.

Process Tanks - Fluid containers in which batch treatment processes are accomplished; geometry and size of these tanks are dependent on the specific operation.

Process Volume - The total volume of wastewater that must be handled during a certain unit process.

Pump Rating - The volume, headloss and type of wastewater that a pump can handle in a certain situation. Defined by the fluid flow (GPM) and the Total Dynamic Head (ft); these are the two coordinates of the pumping curve from which the pump efficiency and horsepower may be read.

Reactant - A substance or chemical participating in a reaction,in this situation considered the chemical being added to a solution of wastewater.

Reduction - The chemical reaction which involves a gain of electrons by the waste species being treated.

Regeneration - A process by which the concentrated solution of the exchangeable ion is passed through the bed. The contaminant is then collected in this solution.

Saturation - A state of solution at which time it is in equilibrium with excess solute and no more solute can be placed in solution.

Scaleup - Scaleup is the translation of bench test values to large scale process units.

Sedimentation - The removal of solid particles from a suspension by gravity settling.

Series Operation - A mode of operation in which a wastewater is treated by passing the entire flow through successive process operations.

Settling Rate - The speed with which a discrete particle falls through the solution expressed in units of distance over time.

Sludge - The concentrated solids after sedimentation.

Slurry - A mixture of solids and liquid (usually water).

Specific Gravity - The ratio of the mass of a solid or liquid to the mass of an equal volume of distilled water at 4°C or of a gas to an equal volume of air or hydrogen under prescribed conditions of temperature and pressure.

Storage Tanks - Fluid containers such as equalization tanks and backwash storage tanks which do not contain the process operations but nevertheless are necessary to accomplish the treatment scheme.

Supernatant - The clarified layer of wastewater above the sludge layer after solids removal.

Surface Blinding - The situation which occurs in a filter due to the hydraulic gradation during backwash. The fine media is near the top of the bed so very rapid lead loss occurs in the first inch of bed depth.

Time to Desludge - The amount of time needed to desludge. It depends on the solids pumping capacity and the volume of sludge to be removed.

Underdrain - A mechanical barrier used to separate the cleaned water from the media and to distribute the filter and backwash flows evenly over the filter area.

Uniformity Coefficient - The ratio of the size such that 60% by weight is smaller than the effective size i.e., the 60%/10% size.

Viscosity - A measure of the amount of resistance to flow. The higher the "viscosity" the more difficult it is to make the fluid flow.

Volume of Spill - The entire volume of area contaminated by a spill which must be treated or otherwise handled.

8.0 STANDARD OPERATING PROCEDURES DURING CLEANUP

8.1 SAMPLING PROCEDURES

The collection and subsequent analyses of samples is important in evaluating the progress of the spill cleanup. As stated in Chapter 3 of this manual (Methodology for Spill Assessment), it is also important to collect samples as soon as possible after the spill occurs for spill identification and assessment and for later use as evidence. Likewise, it is important to collect samples at the beginning of and during the cleanup operation to document the progress of the cleanup. The general sampling methodology described here may be applicable to all situations, although the EPA "Field Detection and Damage Assessment Manual" (5) should be used as a guideline when samples are to be collected specifically for assessment or enforcement purposes.

8.1.1 Method of Sampling

There are two methods of sample collection: automatic and manual. "Automatic" refers to the use of an automatic sampler to collect samples while "manual" refers to collection of samples by a person at the scene. Sampling at the scene of a spill will usually be performed manually because of the emergency and temporary nature of the situation. Also, the presence of personnel on the scene may make it convenient and economical to take manual samples. Guidance on selection and use of automatic samplers can be found in other publications (65-67). The following discussion will assume manual sample collection although the theory could also apply to the use of an automatic sampler.

8.1.2 Type of Samples

There are two types of samples which can be collected for analysis:

1. Grab (discrete samples).
2. Composite samples.

Grab or discrete samples characterize the water quality at a particular instant in time. The purpose of a composite sample is to mix discrete samples in such a way to represent the average characteristics over a period of time. In addition to generating an average value, compositing is often done to reduce the analytical load placed on the laboratory.

The choice of the type of sample should depend on the objective of the sampling and the variability of the water. If the variability of the parameter of interest is low (that is, if the concentration of the parameter of interest changes little over time), then a grab sample may characterize the quality adequately. On the other hand, if the variability is high, then a composite should be formed from grab samples taken at short intervals, or the grab samples themselves should be collected and analyzed. If nothing is known about the variability of the water, then grab samples should be collected and analyzed initially to determine the variability of the water. Judgment will have to be exercised in terms of the allowed variability. As a general rule, though it is wise to form a composite sample for analysis unless directed otherwise.

8.1.3 Types of Composite Samples

A composite sample is a sample formed by mixing discrete samples taken at periodic points in time or consisting of a continuous portion of the flow. There are four commonly used methods of forming composites;

1. Constant time - constant volume: samples of equal volume are taken at equal increments of time and composited to make an average sample.
2. Constant time - volume proportional to flow increment: samples are taken at equal increments of time and are composited proportional to the volume of flow since the last sample was taken.
3. Constant time - volume proportional to flow rate: samples are taken at equal increments of time and are composited proportional to the flow rate at the time each sample was taken.
4. Constant volume - time proportional to flow increment: samples of equal volume are taken at equal increments of flow composited.

In the case of continuous sampling the time intervals in methods 1 and 3 would be zero.

In many cases where a constant-speed pump is used, the treatment rate will be constant so that the volume - proportional methods are identical to the constant time-constant volume method. In this case the constant time - constant volume method should be used. Continuous sampling is best when it is feasible. Where the treatment rate is variable, a flow-proportional compositing method should be used. Methods 2, 3, and 4 all give similar results and the method which is easiest to apply should be chosen. Methods 1, 2, and 3 are the easiest to use since the time interval is constant and a timer can be set to remind personnel to collect a sample. If a totalizer is provided on the flow measurement device, method 2 should be used. If a totalizer is not available but the record can be obtained from a flow chart, the volume treated since the last sample was taken can be estimated from the flow curve.

8.1.3.1 Mechanics of Compositing - For the "constant time-constant volume" method, the contents of all the bottles can be poured into one container, mixed, and the desired volume of sample withdrawn, assuming all the bottles contain an equal volume. Alternately, the contents of each discrete bottle can be mixed and an equal volume, as calculated below, can be taken from each bottle for the composite;

$$V_d = \frac{V_c}{n}$$

V_d = volume of each discrete sample to be used

V_c = composite volume desired

n = number of discrete samples

For the "constant time - volume proportional to flow increments" method, the volume of each discrete sample to be used for the composite can be calculated as follows:

$$\frac{V_d}{V_c} = \frac{F_s}{F_t} \quad \text{or} \quad V_d = \frac{F_s}{F_t} \cdot V_c$$

Where

V_d = volume of the discrete sample to be used

V_c = composite volume desired

F_s = flow volume since last sample

F_t = estimated total flow volume

For the "constant time - volume proportional to flow rate" method, the flow rate should be noted at the time each of the discrete samples was collected. Then the portion of each discrete sample to be used for the composite can be calculated from the equation:

$$ax + bx + cx = V_c$$

Where:

a, b, c = flow rates when discrete samples were taken

x = volume of sample/unit of flow

V_c = composite volume desired

So that

ax = volume of discrete sample "a" to be used

bx = volume of discrete sample "b" to be used

cx = volume of discrete sample "c" to be used

3.1.3.2 Sampling a Batch Process - A single grab sample or a number of grab samples composited will often adequately characterize the discharge of effluent from a batch process. However, if a single sample or a small number of samples are to be used it is imperative that the contents be thoroughly mixed prior to sampling or in the case where quiescent conditions must be maintained, a number of samples at various locations throughout the process container should be taken.

8.1.4 Sampling Location and Parameters

As a general rule it is recommended that samples be taken from the influent and effluent of each process during the entire time of operation. This will not necessarily result in an overbearing number of samples since many samples will serve as the effluent from one process and the influent to another process. Also, samples taken at frequencies as low as a few minutes apart can be composited so that only one sample will result for subsequent analysis.

Although it is obvious that the most critical sample to be taken is the final effluent sample, there are many significant reasons for sampling at other locations. Sampling of the raw flow coming to the treatment process is important since this will allow a determination of the mass of contaminant being removed when the raw is compared to the final effluent. This can become especially critical in cases where it is difficult to get a representative sample of the contaminated watercourse and the only operational way of determining the progress of cleanup is to measure the mass removed and compare this to the original mass spilled.

Taking samples between treatment processes serves many purposes also. Samples allow a determination of the efficiency (or lack of efficiency) of a certain process and then a decision can be made as to whether further operation of this process is required. Also, where filtration, adsorption or ion exchange is used, sampling before and after a process allows calculations of the mass of solids, organics, ions, etc., that have been removed by the process and it can be estimated in advance when backwashing, regeneration or replacement will be required. This will prevent the situation of having to stop all operations because a filter has clogged or a column has broken through when these problems could have been remedied during a previous "down time". By analyzing samples for such parameters as suspended solids, total organic carbon, turbidity, etc., in addition to the hazardous material of concern, it will be possible to maintain good process control. Also, some of these analyses can serve as indicators of the hazardous material requiring fewer analyses of the hazardous material itself, which oftentimes involves complex, expensive and long analytical procedure.

8.1.5 Sample Containers

Samples must be taken into appropriate sample containers to reduce the possibility of contamination or adsorption which will yield incorrect results. The container must be completely clean and equipped with a tightly fitting cap. Organic hazardous materials must be contained in a glass jar or bottle to reduce adsorption to the container walls. Specifically, oils and grease, pesticides, or even short chain organic compounds should be placed into glass containers. Other materials such as metallic salts, can be stored in plastic containers with no adverse effect.

Sample containers should be provided from the nearest analytical laboratory to insure use of the proper type or, if necessary, the bottles can be purchased from a local bottle supplier. If possible, use wide mouth containers with a lined cap except where interaction between the sample and cap material must be modified. (Then use narrow necked containers). If commercial sample bottles can not be obtained, wide mouth canning jars can be used if an aluminum foil liner is provided. Where a plastic container is applicable, distilled water can be purchased, the bottles emptied and the containers used when no other bottles are available. However, the use of these bottles is not recommended without specific instructions from the OSC.

To clean sample containers prior to reuse, the following procedure has been found to be effective:

1. Wash containers and caps with a non-phosphate detergent and scrub strongly with a brush.
2. Rinse with tap water, then distilled water.
3. Invert to drain dry.
4. If additional cleaning is needed, rinse with sulfuric acid, tap water and distilled water.

In certain cases, sample bottles are further rinsed with chemicals to remove traces of materials left by previous samples. These procedures are outlined as follows:

1. Acid Rinse: If metals are to be analyzed, rinse the container with a solution of one part nitric acid to four parts water, then with distilled water. If phosphorus is to be analyzed, rinse the container with a solution of one part hydrochloric acid to one part water followed by distilled water.
2. Solvent Rinse: If oil and grease or pesticides are to be analyzed, rinse the sample container with hexane, then acetone, and distilled water. The container should have been previously cleaned with acid solution. Treat the container caps similarly.

For long term monitoring, however, the analytical laboratory performing the analyses should provide prepared bottles for sampling.

8.1.6 Sample Preservation and Identification

The purpose of sample preservation is to maintain the constituents of interest in the same concentration as when the sample was collected. Even with preservation, the concentrations of the constituents may be a function of the time between sample collection and analysis. Therefore, for any given preservation method a maximum holding time is also specified. Other factors related to preservation that may affect the integrity of the sample include the type and material of the sample container, sample identification, and the chain of custody for sampling handling. For the preliminary or initial sampling, icing or refrigeration of the samples should be adequate. While not effective for all parameters, icing or refrigeration is recommended as a standard technique since it comes closest to being a universal preservative and does not interfere with any analyses. The use of ice cubes and an insulated chest is usually an effective and convenient method for storage and transport of samples.

For a long term sampling program or for process monitoring samples, the laboratory performing the analyses should be consulted for specific instructions regarding preservation techniques and sample containers.

8.1.6.1 Sample Identification - Once the sample is taken, certain procedures must be followed to allow the identification of the sample and to record the chain of custody. It is important that these techniques be standardized and become a part of normal field procedure.

Each sample should be assigned a unique number to allow easy identification in the field and the laboratory. It is important that the number include relatively few digits so that it will not be abbreviated during successive handling. It is recommended that each person who samples be assigned a roll of peel-back labels. These labels would include the person's initials and sequential numbering. As a sample is taken and sealed, a number will be affixed to the bottle. The label would include sufficient space for added information such as date, preservative added, etc. Then the specifics regarding the sampling location, type of sample, and other pertinent facts would be recorded in the field notebook.

8.1.6.2 Chain of Custody - In cases of litigation, there must be proof of the chain of possession that occurs from the time of sample collection to final destruction. If a sample cannot be traced completely, the validity of the analytical result may be doubtful. Therefore, it is important that procedures for a written record of chain of custody be included as normal field practice. A person has custody of a sample if one of the following requirements is fulfilled:

1. It is in his actual physical possession.
2. It is in his view after being in his actual physical possession.
3. It was locked up by him after being in his physical possession.
4. It was kept in a secured area, restricted to authorized personnel after being in his physical possession.

When the sample leaves his custody, then a record should be made indicating that this has been done.

The most important aspect of field procedures is to keep an accurate notebook. Once the sample is taken and a sample identification label affixed to the container, all pertinent information should be recorded in the notebook. The following information should be included:

1. Sample identification number.
2. Date and time of collection.
3. Location of sampling point in detail.
4. Method used to collect the sample.
5. Volume collected and type of container.
6. Preservation method.
7. Analyses to be performed on the sample.

The person performing the actual sampling should be certain to sign and date the record and, if possible, include the signature of a witness in the sampling party.

After the labeling and notation, the sample should either be placed in a chest which will be sealed or a seal should be placed on the container cover. The seal should be of a material which will readily indicate any tampering. Then the person performing the sampling should record in the field notebook how the sample was transported to the lab and indicate if any analysis request sheet was sent with the sample.

If the sample was shipped, all receipts or shipping identification numbers should be kept in the field notebook along with the address of the recipient. The signature of the person receiving the sample should also appear in the notebook. The time and location of the sample while it was in custody of the sampling personnel should also be recorded in the notebook.

Whether or not a rigorous chain of custody procedure will be required for all treatment process samples will be a decision of the OSC and his legal advisors. However, it is estimated that these procedures will at least be required for the raw samples which may supply required data in later litigation.

8.2 RECORDS

The importance of keeping written records cannot be emphasized too strongly. As documentation of the events surrounding the spill and its cleanup, these written records may have important legal implications particularly in cost recovery or reimbursement. The records may also serve as a learning tool in that the knowledge gained from the spill can be applied to future spill situations. It is a good practice after the spill is cleaned, and the emergency is over, to go back and assess the measures taken at the scene. Evaluation of this sort is important in improving response techniques. A record of the progress being made in the cleanup is also important in making decisions at the scene of the spill.

It is recommended that the OSC keep in a permanent bound book a log or diary of the chronological events from the minute of notification of the spill until the cleanup and his duties are completed. All events of any significance should be recorded in the log with notation of the date and time. The information should include records of flow, operation, maintenance, sampling, fuel used, problems encountered, telephone conservations, meetings held, orders issued, weather observations, etc. The log should be kept in a bound, sequentially numbered notebook. Entries should be made in the log immediately and the date and time indicated. No pages should be removed from the notebook. If a page is ruined, it should be marked "VOID". Important observations involving judgment and sampling records should be signed by the principal investigator and countersigned by a witness.

The important records that should be kept in the notebook can be listed as follows:

1. General events - for each day start/stop times for cleanup activities, arrival or procurement of equipment, documentation for authorization, weather observations.

2. Treatment - gallons treated by each process, hours of operation of each process, maintenance needed and/or performed, fuel used, equipment breakdowns, ultimate disposal.

3. Sampling - records of sampling, sample preservation methods, and destination and analyses required of samples.

4. Personnel - a record of all personnel on site, their function, and the actual times present should be recorded. This is especially important for those personnel, whether from a government agency or third party contractor, associated with the cleanup/treatment operation itself. It is imperative that the OSC develop a rigid communication network with the person in charge of the cleanup/treatment operation so that the OSC knows at all times the status of each operation and the personnel attending the respective operation.

SECTION V

METHODOLOGIES FOR SPILL PREVENTION

IN-PLANT SPILL PREVENTION

Management Considerations

The full utilization of proper plant design and effective control systems is essential for an effective spill prevention program. All control systems are of little value unless backed by management committed to utilizing these systems to their fullest extent. It is generally recognized that assignment of responsibility to the smallest supervisory unit practicable is an effective management approach to improve performance. In spill prevention this unit would be the smallest group of facilities that are physically separable from others in terms of measurable pollutional loadings.

Management considerations for the prevention of spills are multitudinous. Spill prevention objectives, investigation of spills to avoid a repetition, and promotion of open and frank communication channels should be some of the prime management objectives. All of these objectives aid in the rapid identification of spill sources and the minimization of spills (68).

Spills may be caused by mechanical failure or personnel error, or more rarely, by fire, explosion, power failures, or "acts of God". However, since most spills are a result of mechanical failure and/or personnel error, the following measures can go a long way in preventing or minimizing their occurrence (69):

Sound basic design

Thorough training of operating, technical and maintenance personnel

Strict job responsibility

Sound process control and alarm and monitoring systems

Proper maintenance of equipment and facilities

Maintenance should review existing operating and maintenance procedures and develop vulnerability studies. From these studies critical portions of the manufacturing process can be singled out and modified to decrease the probability of a hazardous spill. The spill prevention program of any plant should include an action diagram or plan to be followed when a spill occurs. In this plan, responsibilities should be definitely assigned (preferably by name) to establish the chain of command so that there is no confusion or time wasted. A primary consideration should be to prevent the spill from contaminating the environment outside the plant (surface or groundwater, municipal sewers, soil, etc.).

Physical means of stopping spills from reaching areas outside the plant should be provided. Examples would include: maintaining neutralizing agents near bulk storage areas, maintaining personal protective safety equipment in potential spill locations so that spills may be localized. When lighter than water chemicals are handled, adequate length of flotation spill-contaminant booms or absorbent booms should be available along with the proper means to deploy them. An adequate supply of dispersants (that have been approved by state authorities) should be stored at the plant for treatment of spills (70).

Plant Drainage

Proper plant drainage is a prime means of containing hazardous material spills and preventing them from reaching receiving waters. When a drainage system is designed, consideration to entrapping as much potentially polluted water as possible and diversion of these waters to the proper final destination are the predominant concerns (71).

The following recommendations relative to plant drainage were part of the Guidelines for Spill Prevention, Containment and Countermeasure Plans (SPCC) (72).

1. Drainage from diked storage areas should be valve-restrained to prevent a spill or other excessive leakage of a product into the drainage discharge or in-plant effluent treatment system.

2. Valves used for the drainage of diked areas should, as far as practical, be of manual, open-and-close design. The condition of the retained stormwater should be determined before drainage, especially if such drainage of impounded waters goes into watercourses and not into wastewater treatment plants.

3. All plant drainage systems, if possible, should flow into ponds, lagoons, or catchment basins designed to retain materials less dense than water. Consideration should also be given to possible chemical reaction, if spilled chemicals are commingled.

4. If plant drainage is not engineered as above, the final discharge of all in-plant drainage ditches should be equipped with a diversion system that could, in the event of an uncontrolled spill, be returned to the plant for treatment, the objective being to work toward a closed-cycle system.

5. Where drainage waters are chemically treated in more than one treatment unit, natural hydraulic flow should be used. If pump transfer

is needed, two "life" pumps should be provided, and at least one of the pumps should be permanently installed.

Monitoring Process Variables

The monitoring of physical and chemical quantities involved in plant processes is an extremely useful aid in avoiding hazardous spills. Either specific apparatus or entire process systems are commonly monitored. Normally process variables such as temperature, pressure, flow, specific gravity, viscosity, and chemical composition are measured. Often these measuring devices are used with automatic controls which regulate process variables to achieve optimum utilization of raw materials. In order to do this, the control keeps process variables within predetermined specifications. Such a device may also have a vital role during abnormal situations triggering corrective action, or, in extreme cases, in safely shutting down the system.

When monitoring hazardous materials, it is normal to use redundant or backup instrumentation. Because the sampling probe is in direct contact with the usually extreme condition of heat and corrosive vapors, it is the least reliable part of the system. Frequently it is desirable to use a device having a different principle of measurement as a backup unit. An example of this is the use of a resistance bulb to sense the operating temperature of a reaction vessel. The backup device could be a thermocuple.

After determining that something is wrong, the proper corrective action should be initiated. The corrective action depends entirely on the nature of the hazard and the consequences to the plant or operation. An electrical interlock system to shut down pumps and close valves leading to the process unit which is malfunctioning is a common device to prevent more material from being added to a potential spill.

Monitoring equipment should warn personnel that an operating abnormality has occurred. Commonly a flashing light and horn, which can be silenced by the operator, are used to attract the operator's attention to a particular control loop. Operation of the alarm should be independent of any control mechanism so that the alarm will still function properly even though a malfunction might occur in the control mechanism. Further monitoring equipment, such as a siren, should be employed to signal hazardous situations that might require evacuation of personnel from the area. Monitoring systems can also be obtained which use prerecorded messages to indicate the nature of the problem for the operator (73).

Inventory control systems and materials balance determinations may also indicate if leakage or spillage is occurring. The hazard potential of the following should be determined (69).

Raw materials
Intermediate process compounds
By-products
Waste materials
End products

In-Plant Piping

Pipelines used for in-plant transportation of hazardous materials should be constructed or modified so that the following SPCC guidelines are adhered to (72).

1. Each product pipeline should be clearly marked by lettering (coded or otherwise), color banding, or complete color coding to indicate the product transferred therein. The coding should conform with company policy or standard plant practice which, in turn, should conform with state or federal requirements.

2. Each oil or hazardous material product-fill line which enters a tank below the liquid level should have a one-way flow check valve located as closely as possible to the bulk storage tank. In addition to confining the product to the tank, in the event of valve or pipeline failure, the check valve should permit overhaul of the main shut-off valve and should aid in preventing shock loading of the pipeline and valves from a "slug" of the tank content caused by backflow into an empty fill line. As far as practical, the product flow in suction lines should be controlled by use of a positive displacement pump.

3. Buried pipelines should be avoided. However, buried installations should have a protective wrapping and coating and should be cathodically protected if soil conditions warrant. A section of the line should be exposed and inspected annually. This action should be recycled until the entire line has been exposed and examined on a regularly established frequency. An alternative would be the more frequent use of exposable pipe corridors or galleries.

4. When a pipeline is not in service, the terminal connection at the transfer point should be capped or blank-flanged, and marked as to origin.

5. Wood-to-metal should be avoided as a pipeline support since it is apt to retain moisture and cause pipeline corrosion which, when coupled with the abrasive action caused by the pulsating action of the line, could cause line failure with resulting leakage. Supports should be designed with only a minimum point of surface contact that allows for the pulsating movement (expansion and contraction) of the line (i.e., rollers).

6. All above-ground valves and pipelines should be subjected to a regular monthly inspection at which time the general condition of items, such as flange joints, valve glands and bodies, catch trays, pipeline supports, locking of valves, and metal surfaces, should be assessed.

7. Elevated pipelines should be subjected to constant review to

insure that the height of vehicular traffic granted plant entry does not exceed the lowermost height of the elevated line; gate check-in and in-plant travel routes warrant attention in this respect.

8. As far as practical, all pumps should be located as close as possible to the storage tank.

9. Flapper-type drain valves should not be used to drain diked areas. Such drain valves should be of manual open and close design, and they should be kept in the closed position when not in service. The drain lines from dike areas should drain directly or indirectly into treatment or holding tanks or ponds or catchment basins.

Solid Material Storage

Solid material storage should conform to the following SPCC guidelines (72):

1. The open stockpiling of ores, chemicals and minerals should be discontinued. Piles of bulk material should be covered to prevent leaching and runoff. If open shed-like structures are used for bulk storage, retention curbing should be provided around the perimeter of the pile, or perimeter drainage trenches should direct runoff into a suitable wastewater treatment facility.

2. Bulk storage should not be positioned on the natural earth. Storage pads of concrete or other impervious materials should be used as a base to prevent ground water leaching and percolation into the earth.

3. Metal and fiber containers should be loaded, stored, and unloaded so as to minimize possibility of container damage. The containers should be stored in a covered area, off the ground in a manner which will preclude damage and weathering to the container, and subsequent leakage. The area itself should be provided for drainage to a treatment facility in an analogous manner to diked storage tank areas.

4. If some conainers contain corrosive substances, these should be stored so that leakage of these substances will not corrode through adjacent containers.

5. All items outlined under this heading should be periodically inspected to insure physical and mechanical integrity of the drainage and containment systems.

Bulk Storage

Bulk storage of materials should conform to the following SPCC guidelines (5):

1. No tank should be used for the storage of oil or hazardous substances, unless its material and construction are compatible with the material stored.

2. All bulk storage tank installations should be planned so that a secondary means of containment is provided for the entire contents of the largest single tank. Dikes, containment curbs and pits are commonly employed for this purpose, but they may not always be appropriate. An alternative system would consist of a complete drainage trench enclosure arranged so that a spill could terminate and be safely confined in an in-plant catchment basin or holding pond.

3. Drainage of rainwater from the diked area into a storm drain or an effluent discharge that empties into an open watercourse, lake, or pond, and by-passing the in-plant treatment system may be acceptable if:

    1. The by-pass valve is normally locked closed.

    2. Thorough analysis of the rainwater ensures compliance with applicable water quality standards.

    3. The by-pass valve is unlocked, and relocked following drainage under the supervision of responsible management.

    4. Adequate records are kept of such events.

4. The storage tanks located immediately adjacent to the dike itself should be oriented with respect to the dike so that no manholes face the dike. This is considered desirable, so that if a manhole fails, the resulting discharge from a full tank will not be aimed over, or at the dike.

5. If storage tanks located immediately adjacent to the dike itself are equipped with fill lines which enter the tank near the bottom and if the fluid pumped has suspended abrasive material, the discharge into the tank should be on the dike side, discharging against the tank side away from the dike. Alternatively, a baffle plate located inside the tank opposite the pump discharge in the area apt to be abraded, may be provided.

6. Buried storage tanks represent a potential for undetected spills. A buried installation, when required, should be wrapped and coated to retard corrosive action. In addition, the earth should be subjected to electrolytic testing to determine if the tank should be further shielded by a cathodic protection system. Such buried tanks should at least be subjected to regular hydrostatic testing. In lieu of the above, arrangements should be made to expose the

outer shell of the tank for external examination at least every five years. A means of conducting regular internal examinations of the tank at five-year intervals should be provided (down-hole television, etc.).

7. Partially buried tanks for the storage of oil or hazardous materials should be avoided, unless the buried section of the shell is adequately coated since partial burial in damp earth can cause rapid corrosion of metallic surfaces, especially at the earth/air interface.

8. Above-ground tanks, depending on design (floating roof, etc.) should be subjected to integrity testing, either by hydrostatic testing, visual inspection, or by a system of nondestructive shell thickness testing. When the latter system of integrity testing is used, comparison records of shell thickness reduction should be maintained.

9. The foundation and/or supports of all bulk storage tanks should be subjected to at least annual examination by a person with the technical competence to assess the condition of the foundation and/or supports.

10. To control leakage through defective integral heating coils, the following factors should be considered and applied:

    a. The past life span of internal steam coils should be determined, and a regular system of maintenance and replacement that does not exceed the anticipated life span should be established.

    b. To reduce failure from corrosive action, prolong life, and reduce replacement costs, the temperature and environment have to be carefully considered when selecting heating coil materials.

    c. The steam return or exhaust lines from integral heating coils which discharge into an open watercourse should be monitored for contamination, or passed through a settling tank, or skimmer, etc.

    d. The feasibility of installing an external heating system should also be considered.

11. Each bulk storage tank should be externally examined at least once a month. Each inspection should include an examination of streams, rivets, nozzle connections, valves, and pipelines directly connected to the tank.

12. New and old tank installations should, as far as practical, be fail-

safe engineered or updated into a fail-safe engineered installation. Consideration should be given to providing the following devices;

a. High liquid level bell or horn alarms with an audio signal at a constantly manned operating or listening station; in smaller plants and audible air vent may suffice.

b. Low liquid-level alarms with an audio signal at a constantly manned operation of listening station; such alarms should have a non-bypassing reset device that can be readjusted to a given operating level following tank fill or liquid removal.

c. High liquid-level pump cutoff devices set to stop flow at a predetermined tank content level.

d. Direct audible or code signal communication between the tank gauger and the pumping station.

e. At least one fast response system for determining the liquid level of each bulk storage tank such as digital computers, telepulse, or direct vision gauges.

13. "Normal" plant effluent should be constantly monitored by a proven monitoring system, and any deviation from normal should be engineered to activate a visible readout recorder with an audible alarm that can be heard at a constantly manned operation or listening station. If practical, the monitoring device should be designed to operate a bypass to release the effluent discharge into a holding pond.

14. Visible product leaks from tank seams and rivets should be promptly corrected.

15. Tanks should not be used with the knowledge that the "head" or "top" is in a corroded-through condition. Action should be taken to drain such tanks and repair the defective member as promptly as possible.

16. When practical, each bulk storage tank should be lettered (code or otherwise) or color coded to indicate its chemical content, the Manufacturing Chemists Association or Department of Transportation coding being preferred, and the coding should duplicate those used for chemical transportation identification.

17. The use of wooden tanks should be confined to water storage and should be avoided for liquid chemical storage.

The Manufacturing Chemists' Association has developed a checklist to aid in developing spill prevention and control programs for chemical plants. This checklist is presented in the end of this section.

SPILL PREVENTION DURING TRANSPORT

General Considerations

The Code of Federal Regulations (CFR), Title 49, Parts 170-178 was originally published by the Department of Transportation to control surface transportation of hazardous materials. For air transport, more specific controls were deemed necessary and the Federal Aviation Regulations (FAR), Vol. VI, Part 103 were drafted to modify 49 CFR. CAB 82 is an air line tariff which must be followed where it is more restrictive than 49 CFR or FAR 103. The International Air Transport Association (IARA) Restricted Articles Regulations must also be followed for all U.S. import and export shipments. Within the U.S., state and local agency requirements must also be met.

All the regulations are designed to prevent spills from occurring and to protect life and property. In complying with the regulations, the following activities are required.

1. Identification by proper DOT name
2. Classification by DOT hazardous material class
3. Packaging
4. Marking and labeling
5. Preparation of shipping papers

Both shippers and carriers are legally obligated to comply with the applicable regulations. Before a shipment is consigned to a carrier, the following must be checked by the shipper (74).

1. That DOT authorized containers have been used.
2. That proper closures have been used and no leaks are evident.
3. That outside packages are properly labeled and have required outside marking.
4. That shipping documents include proper DOT shipping name, hazardous material class, signed certificate, proper count and weight. Abbreviations must not be used for required entries.
5. That non-compatible materials are not tendered in the same shipment. If non-compatible shipments are tendered to the same carrier, make certain that the carrier recognizes the situation. Check the loading and storage charts.
6. That the driver is made aware that the shipment contains a hazardous material.
7. That a carrier representative has an opportunity to approve the

placement, securing and blocking of the material before closing out and sealing the load (if seals are used), if the material is loaded by the shipper's personnel.

8. That placards are properly displayed before the carrier leaves.

The carrier should check that the shipper has met his requirements before accepting a shipment. In addition, the carrier's personnel have certain responsibilities regarding spill prevention (75).

Freight Handlers:

1. Must have broad hazardous material knowledge involving proper DOT shipping names, classes, required packaging, compatibility, labeling, marking requirements, placarding and shipping documents.

2. Must check hazardous material freight against documents. If they do not check out, make certain that the discrepancies are resolved before freight is allowed to move any further.

3. Must refuse to accept hazardous material freight from shippers or interline carriers if the shipping documents are improperly prepared or do not check out with the freight involved or if the containers are leaking, damaged or otherwise improper.

4. Must inspect all hazardous material freight for leakage or damage each time it is handled.

5. When damaged containers are discovered, must isolate and make certain they are not moved until they are in proper condition for further transportation. Make certain that all container information is obtained for use in preparing the required report to the Department of Transportation. (NOTE - In some instances immediate telephone notification to DOT is also required).

6. When contamination occurs or when it is necessary to dispose of hazardous materials or containers, must make certain that a qualified individual supervises such activities.

7. Must make certain that non-compatible hazardous materials are not loaded into the same vehicle.

8. Must make certain that proper placards are placed on vehicles when required and that placards are removed or covered when not required.

9. Must make certain that hazardous material containers will not be damaged by other freight or by nails or rough sides and flooring within the vehicle.

10. Must make certain that all hazardous material is properly blocked

and secured before closing out vehicle.

11. Must make certain that class A or B poisons are not loaded with foodstuffs or other contaminatible cargo.

12. Must be familiar with, and have available for reference, provisions of 49 CFR Part 177, Subpart B, titled "Loading and Unloading" and Subpart C, titled "Loading and Storage Chart".

Drivers

1. Must have a broad hazardous material knowledge involving proper DOT shipping names, classes, required packaging, compatibility, labeling, marking requirements, placarding and shipping documents.

2. Must have in his possession, and available for immediate use, proper shipping papers covering all hazardous materials loaded on his vehicle.

3. Must have specific instructions (preferably written) as to handling procedures in case of hazardous material incidents.

4. Must know what to do and what information to pass on to firemen, police and others should emergency arise.

5. Must report all discrepancies and irregularities observed during trip (including such things as leaking containers or defective tank truck valves).

6. Must understand their responsibilities as to attendance requirements when transporting a hazardous material.

7. Must refuse to accept hazardous material freight from shippers or interline carriers if the shipping documents are improperly prepared or do not check out with the freight involved or if the containers are leaking, damaged or otherwise improper.

For specific requirements shippers and carriers should check the appropriate regulations. These regulations can be obtained as follows:

49 CFR	Superintendent of Documents U.S. General Printing Office Washington, D.C. 20402
CAB 82	Airline Tariff Publishers, Inc. Dallas International Airport P.O. Box 17415 Washington, D.C. 20041

IATA Restricted
Articles Regulations
International Air Transport Assn.
ATTN: Mr. Gordon Young
1155 Mansfield Street
Montreal, Quebec 113PQ

In addition to these requirements it is recommended that emergency information cards, describing actions to be taken in emergencies, accompany the shipment. These Chemcards (Cargo Information Cards for Water Transportation) were developed by and are available from the Manufacturing Chemists' Association, 1825 Connecticut Avenue, N.W., Washington, D.C. 20009.

Railroad

Equipment Features - The Association of American Railroads (AAR) favors the use of relief valves on tank cars instead of rupture disks since a relief valve will close once the pressure is reduced (76). The DOT Federal Railroad Administration, Hazardous Materials Branch recommends that valves be placed internally or otherwise protected if they are to be placed on the bottom of tank cars, as is becoming more common (76). Also recommended are protective "skids" to minimize contact of the tank with exterior forces in the event of an accident. The AAR has designed a coupler ("shelf coupler") which is less likely to disengage due to vertical motion at the time of derailment (76). If the couplers remain together, they are unlikely to puncture a car.

Preventive Maintenance and Safety Precautions - Many spills can be prevented and the severity of those which do occur decreased by the exercise of maintenance checks and safety precautions (76).

1. Prevention of overloading - Pressure can be generated by thermal expansion when a tank car is overloaded. This can cause failure of a rupture disk or opening of a relief valve.

2. Routine inspection - Tank cars should be routinely inspected for dents, gouges, or other damage. The running gear should also be checked. Gaskets should be routinely replaced, say, on an annual basis. Caps and plugs should be routinely inspected and replaced as necessary.

3. Closing of valves - The importance of tightly closing valves should be emphasized to all employees.

4. Placarding - The placarding regulations established by DOT should be observed for all hazardous cargo.

5. Positioning of cars - The DOT regulations specifying the positioning of cars (3) containing hazardous substances should be followed closely.

The following guidelines have been provided by EPA for the development of Spill Prevention, Containment and Countermeasure (SPCC) Plans by industry (72).

Tank Car and Tank Truck Loading/Unloading

Relative to tank car and tank truck loading/unloading procedures, the requirements and regulations of the Department of Transportation should be met. The following recommendations should be emphasized.

1. A system of containment curbs should be used for tank truck unloading areas, using ramps to provide truck access into the confines of the containment curb. The curb enclosure should be designed to hold at least the maximum capacity of any single tank truck loaded or unloaded in the plant.

2. A trenching system should encompass each railroad tank car unloading area. The trench should be designed to carry away any spill to a catchment basin or holding pond, at least equal in capacity to the capacity of the largest tank car loaded or unloaded in the plant.

3. As a fail-safe precaution, an interlocked warning light or physical barrier system, or warning signs, should be provided in loading/unloading areas to prevent vehicular departure before complete disconnect of flexible or fixed transfer lines.

4. Prior to filling and departure of any tank truck, the lowermost drain and all outlets of such vehicles should be closely examined for leakage, and if necessary, tightened, adjusted, or replaced to prevent liquid leakage while in transit.

Trucking

Equipment Features - Anti-jackknife devices are effective but are expensive and limit maneuverability. Bottom-loading and vapor-recovery units help to prevent spills and air pollution (76).

Preventive Maintenance and Safety Precautions - Routine inspection and maintenence procedures should be performed as for railroad cars. In the case of a truck, though, the driver may have greater personal responsibility and he should inspect the rig before leaving for his destination to make sure it is safe to operate. The driver should make sure he has the shipping papers and that they contain sufficient information to identify the cargo (chemical name, shipper, manufacturer, telephone numbers). Placarding of the truck should be performed as required by DOT regulations. The driver should consider the nature of his cargo in judging the appropriate driving speed. Also DOT regulations on drivers working hours per week should be strictly observed.

SPCC Plan guidelines for tank truck loading/unloading were given in the discussion on railroads.

Maritime

Equipment Features - Probably the construction feature that is most significant in preventing maritime spills of bulk cargoes is the doublehull vessel. For this type of vessel in many cases a collision or grounding would affect only the outer shell and not the actual container of the chemical cargo.

Preventive Maintenance and Safety Precautions - Routine inspection and maintenance should be performed for vessels and loading/unloading facilities. These procedures are covered in the EPA SPCC Plan Guidelines (77).

Barge Loading and Dock Site Facilities

Spill prevention, detection, containment, and safety practices here dictate that:

1. All flexible hoses must be hydrostatically tested annually, and inferior hoses must be discarded and replaced.
2. Barge loading lines must be routinely inspected during loading operations.
3. Adequate mooring lines forward and after are secured to all barges to minimize movement during loading.
4. Hoses must be water-flushed into the barges after loading.

Transporting Barges Through Territorial Seas

Transporting barges through territorial seas to the disposal sites must comply with the U.S. Department of Transportation regulations. Special emphasis must be applied to insure that;

1. No permittee will knowingly send a barge to sea with leaks or defects that can lead to a spill.
2. The tugboats employed for transporting the waste barges must be inspected and must comply with U.S. Coast Guard regulations.
3. The barge must carry the following permits and certificates;
    a. An Environmental Protection Agency ocean dumping permit.
    b. A U.S. Coast Guard consolidated certificate of enrollment and license for coasting trade

c. The International load line certificate issued by the American Bureau of Shipping.

Drummed Wastes

1. Drums are stored on curbed concrete pad while the barge shipment is being assembled. In the event a drum is damaged, any liquid spilled must be soaked up and redrummed. Solids spills must also be redrummed.

2. The barge is equipped with a toe board and railing to prevent slippage.

3. The drums are stored on deck in two rows with a walkway in the center. Each row of drums is secured firmly together with two strips of 5 cm (2 in.) steel binding to prevent shifting of the cargo.

4. If, in spite of the precautions taken to prevent emergecies and accidents, a drum is dumped or lost in any manner and/or location other than that specified, regardless of the circumstances, the U.S. Coast Guard must be notified immediately and action will be taken in accordance with their recommendations. A full report of the incident and action taken must be filed with EPA within 30 days.

Pipeline

Equipment Features - Safety devices have been extensively relied upon because of the extent of pipeline networks. These include fire detection equipment with automatic alarm and shutdown, automatic extinguishing systems, and closed-circuit television. Systems have been developed which monitor the flow and pressure at points along the pipeline. If a variation in pressure is detected, the line can be shut down until the leak is located and repaired (78,79):

Preventive Maintenance and Safety Precautions - Routine inspection and maintenance should be performed on the pipeline system. Aerial inspection is presently widely used to detect leaks or digging activity near the pipeline (76). Markers indicating the presence of the pipeline should be installed at all roads and other crossings where possible dredging or ditching might take place.

Airways

The best preventive measure for an air shipment is to be sure that the hazardous material is properly packaged and identified as to the potential hazard so that it will be properly handled by airline employees. This will be achieved if the regulations on hazardous shipments are followed:

For shipments within the U.S.

Federal Aviation Regulations, Vol. VI, Part 103

Code of Federal Regulations Transportation, Title 49, Parts 170-189.

CAB 82, Official Air Transport Restricted Article Tariff No. 6-D.

For international shipments all of the above plus;

International Air Transport Association Restricted Articles Regulations.

All applicable foreign law.

SAFETY OR PREVENTION DEVICES

Certain specialized devices can be employed by operating personnel as spill prevention and control measures. These devices can basically be used, 1) to provide early warning or detection of a spill, and 2) to contain the spill at an early stage.

Monitoring/Detection Devices

In large industrial plants or industrial rivers the expense of installing detectors may be justified. Union Carbide has successfully used continuous total carbon analyzers, pH meters, and hydrocarbon vapor analyzers for spill detection at its plants (80). Other devices have been found applicable for detecting pollutants in water (81).

Device	Detection of
Catalytic combustion sensor	Volatile organics
Electrical conductivity sensor	Ionic solutes
pH and specific ion probes	Acids, bases, metallic pollutants
Multicolor transmissometer	Less volatile organics
Colorimeter	Heavy metals

It is simpler and often just as effective to monitor a process characteristic rather than the hazardous chemical itself. Characteristics that might be monitored include flow, temperature, tank level and pressure (6). These devices can serve a warning function only or can be tied in to a control device to automatically control, correct, shut down equipment, or provide safe disposal of the overflow. For example, pumps could be shut down and valves closed to prevent a spill from occurring or becoming worse.

Containment/Control Devices

The objective of these devices is to stop or contain the flow of the spill. Excess flow valves are in-line safety devices that act to limit the flow of liquids or gases out of a pressurized system. They will pass normal rates of flow; however, they will close against excess outward flow rates in the event the pressurized system is opened to the atmosphere due to pipe breakage or because of system misoperation. These devices are used extensively in pressurized liquified gases and in chlorine tank car discharge lines (73).

The automatic sealing imbiber valve is simply a metal cylinder with necked openings at each end and filled with imbiber beads retained by supported porous membranes. Relying upon the void volume which naturally occurs in a bed of packed spheres, the valve passes water freely. However, when contacted by a hazardous fluid, the beads swell rapidly, stopping all flow (82).

Other devices such as dikes, curbs, and container plugs are discussed in other sections of this report. Examples of catchment systems that can be used to prevent spilled materials from contaminating the environment are shown on the following pages.

MCA SPILL PREVENTION AND CONTROL CHECKLIST FOR CHEMICAL PLANTS

6.1 DEFINE AND ASSESS THE HAZARDS OF MATERIALS HANDLED

6.1.1 Raw Materials

Have *all* raw materials been considered?

Have the potential consequences of use of each raw material been defined?

Has each raw material been identified in a spill rating guide?

Is the inventory control of raw materials adequate?

Is the purchasing or procurement section aware of raw materials quality control effects on possible hazards?

6.1.2 Intermediate Process Compounds

Have all intermediates been identified?

What are the possible consequences of spillages of intermediate compounds?

Have intermediates been considered in the spill rating guide?

Do you have means for detecting and measuring the losses of intermediate materials and compounds?

6.1.3 End Products

Have all end products been considered?

Have the potential consequences of spills of each end product been defined?

Has each end product been identified in a spill rating guide?

Is the inventory control of end products adequate?

6.1.4 By-Products and Waste Products

Have all by-products and waste products been considered?

Have the potential consequences of spills of each by-product and waste products been defined?

Has each by-product and waste product been identified in a spill rating guide?

Is the inventory control of by-products and waste products adequate?

6.1.5 Rating Guide

Has a rating guide been prepared or considered?

Have the frequency, detectability, consequences, and local conditions factors been considered?

Have all raw materials, intermediates, by-products, waste products, and end products been rated?

Who has access to and uses the rating guide?

6.2 ASSESS THE POTENTIAL OF SPILL OCCURRENCE

6.2.1 Receiving and Unloading

Has the "anything that can happen, will" philosophy been applied?

Are the operations controlled and supervised by dependable and knowledgeable personnel?

Are losses monitored?

Are maintenance and preventive maintenance inspections reporting adequate?

6.2.2 Storage and Transfer

Are all materials inventoried and controlled?

Is the best equipment utilized?

Are small spills reported and properly and promptly handled?

Has the probability of a major spill incident been established?

6.2.3 Process Operations

What is the practice of controlling and reporting emergency discharges?

Are process upsets and equipment failures repetitive? If so, why? Are process errors recognized and reported?

Do the operating personnel know and recognize the detrimental effects of spills and accidental discharges?

6.2.4 In-Process Transfer

What are the practices of controlling and reporting emergency discharges?

Are process upsets and equipment failures repetitive? If so, why?

Are process errors recognized and reported?

Do the operating personnel know and recognize the detrimental effects of spills and accidental discharges?

6.2.5 Laboratory and Pilot Operations

Are the potential ill effects of accidental or unusual discharges recognized?

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Are spill prevention and controls factors applied in planning and design?

Is there adequate consideration of the waste products or hazards influencing feasibility factors in development work?

Is waste control practised in laboratory procedures, sampling, handling, disposal and trial operations?

6.2.6 Shutdown and Clean-up

Are procedures developed with spill prevention and control in mind?

Can the unusual be isolated and handled as a special case?

Are personnel aware that the problem can't be flushed down the drain?

Have personnel been alerted to the unusual hazards involved in start-up and shutdown, especially emergency shutdowns?

6.2.7 Maintenance Procedures

Are maintenance personnel aware of spill prevention and control problems?

Do production, technical and waste control personnel coordinate with maintenance?

6.2.8 Auxiliary and Support Operations

Do these other departments recognize their involvement in spill prevention and control?

Does overtaxing support equipment and operations present spill problems?

6.3 EVALUATE INFLUENCING PHYSICAL FACTORS

6.3.1 Plant Site

Are physical factors such as terrain and proximity to receiving water considerations in planning, prevention, and control of spills?

Do the backup, stoppage, and overflow of waste waters affect the overall programs for spills control?

Are dikes and other containment devices influenced by physical factors of slope, runoff, flooding, soil conditions, etc.?

Is the property underlain by shallow ground waters which would be subject to pollution via percolation of spills through the soil?

6.3.2 Machinery and Equipment

Are the existing plant machinery and equipment significant factors in spill prevention?

Is related auxiliary and support equipment properly maintained?

Does spill prevention and control equipment receive adequate inspection and preventive maintenance?

6.3.3 Buildings and Structures, Yard and Grounds

What is the influence of buildings and other structures in the prevention and control of spills?

Are roof deposits potential spill hazards?

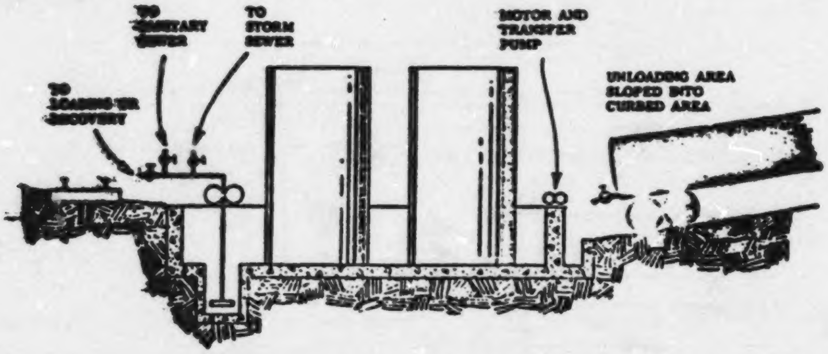
Are ground deposits potential spill hazards?

6.3.4 Operating Areas

Are spilled materials handled promptly and properly?

Do accumulations of small spills present a problem?

Can maintenance be performed without bypassing safety devices and procedures?



Containment curb-type spill catchment system, depressed area form.

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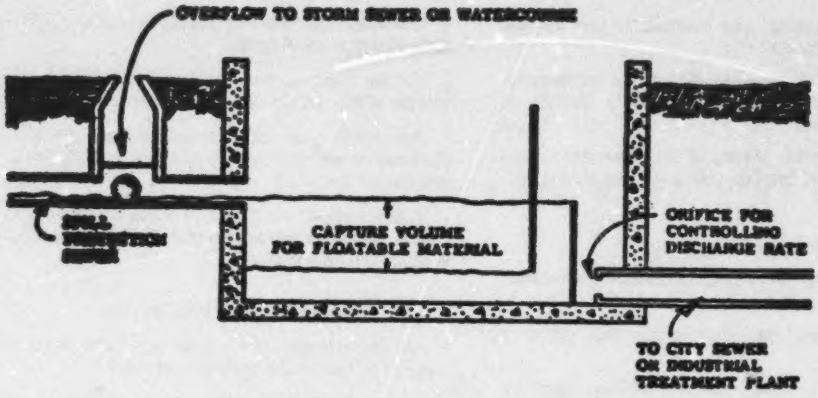

OVERFLOW TO STORM SEWER OR WATERCOURSE
CAPTURE VOLUME FOR FLOATABLE MATERIAL
ORIFICE FOR CONTROLLING DISCHARGE RATE
TO CITY SEWER OR INDUSTRIAL TREATMENT PLANT

Catchment basin system of flow-through type, with orifice-controlled discharge rate.

6.3.5 Sewerage Systems

Are sewers segregated or combined?

Can spills be diverted to minimize effects?

Is the plant sewerage system maintained properly?

Are blockages and back-up flooding a problem?

6.3.6 Storm Water Runoff and Collection

Has the effect of storm water been considered?

Can storm water be diverted away from spill areas?

Are roofs, buildings and ground a source of "Act of God" spill effects?

Are storm water effluents measured, sampled and evaluated?

6.3.7 Utilities and Utilities Transmission

Do spill prevention and control devices have adequate uninterrupted power?

What is the effect of power interruption on alarms, control systems, pumping, etc.?

Do the power plant and water treatment plant contribute to potential for spills?

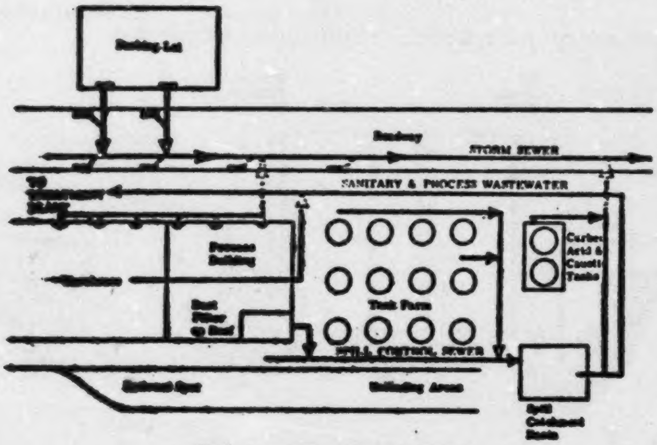
6.3.8 Potential of Natural Disasters

Has the probability of natural disasters been determined or considered?

What areas could be affected by natural disasters?

Can waste treatment ponds be influenced?

Is sewerage back-up a problem?


Roadway
STORM SEWER
SANITARY & PROCESS WASTEWATER
Process Building
Tank Farm
SPILL CONTROL SEWER
Unloading Area
Spill Catchment Basin

Basin-type spill catchment system.

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